VOL. I.

MATERIALS; THEIR DIFFERENCES, CHOICE, AND PREPARATION; VARIOUS MODES OF WORKING THEM, GENERALLY WITHOUT CUTTING TOOLS.

VOL. II.

THE PRINCIPLES OF CONSTRUCTION, ACTION, AND APPLICATION, OF CUTTING TOOLS USED BY HAND; AND ALSO OF MACHINES DERIVED FROM THE HAND TOOLS.

VOL. III.

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VOL. IV.

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VOL. V.

THE PRINCIPLES AND PRACTICE OF ORNAMENTAL OR COMPLEX TURNING.

VOL. VI.

THE PRINCIPLES AND PRACTICE OF AMATEUR MECHANICAL ENGINEERING.

Every Volume to be complete in itself.

TURNING

AND

MECHANICAL MANIPULATION.

INTENDED AS

A WORK OF GENERAL REFERENCE AND PRACTICAL INSTRUCTION

ON THE LATHE,

AND THE VARIOUS MECHANICAL PURSUITS

FOLLOWED BY AMATEURS.

VOLUME III.

ABRASIVE AND MISCELLANEOUS PROCESSES WHICH CANNOT BE ACCOMPLISHED WITH CUTTING TOOLS.

BY THE LATE

CHARLES HOLTZAPFFEL,

ASSOCIATE OF THE INSTITUTION OF CIVIL ENGINEERS, LONDON;
CORRESPONDING MEMBER OF THE AMERICAN INSTITUTE OF NEW YORK,
AND OF THE FRANKLIN INSTITUTE, PHILADELPHIA;
ETC., ETC.

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GENERAL SKETCH

OF THE

CONTENTS OF THE WORK.

VOL. I.

MATERIALS, THEIR DIFFERENCES, CHOICE, AND PREPARATION; VARIOUS MODES OF WORKING THEM, GENERALLY WITHOUT CUTTING TOOLS.

Introduction—Materials from the Vegetable, the Animal, and the Mineral Kingdoms—Their uses in the Mechanical Arts depend on their structural differences, and physical characters. The modes of severally preparing, working, and joining the materials, with the practical description of a variety of Processes, which do not, generally, require the use of Tools with cutting edges.

VOL. II.

THE PRINCIPLES OF CONSTRUCTION, ACTION, AND APPLICATION, OF CUTTING TOOLS USED BY HAND; AND ALSO OF MACHINES DERIVED FROM THE HAND TOOLS.

The principles and descriptions of Cutting Tools generally—namely, Chisels and Planes, Turning Tools, Boring Tools, Screw-cutting Tools, Saws, Files, Shears, and Punches. The hand tools and their modes of use are first described; and subsequently various machines in which the hand processes are more or less closely followed.

VOL. III.

ABRASIVE AND MISCELLANEOUS PROCESSES WHICH CANNOT BE ACCOMPLISHED WITH CUTTING TOOLS.

Grinding and Polishing, viewed as extremes of the same process, and their application both to the production of form and to surface embellishment, in numerous cases to which, from the nature of the materials operated upon and other causes cutting tools are altogether inapplicable. Varnishing, lackering wood and metal, bronzing and miscellanea.

VOL. IV.

THE PRINCIPLES AND PRACTICE OF HAND OR SIMPLE TURNING.

Descriptions of various Lathes;—applications of numerous Chucks, or apparatus for fixing works in the Lathe. Elementary instructions in turning the soft and hard woods, ivory and metals, and also in Screw-cutting. With numerous Practical Examples, some plain and simple, others difficult and complex, to show how much may be done with hand tools alone.

VOL. V.

THE PRINCIPLES AND PRACTICE OF ORNAMENTAL OR COMPLEX TURNING.

Sliding Rest with Fixed Tools—Revolving Cutters, used in the Sliding Rest with the Division Plate and Overhead Motion. Various kinds of Eccentric, Oval, Spherical, Right-line and other Chucks. Spiral and Reciprocated turning. The Spherical Rest, &c.

With numerous Practical Examples.

VOL. VI.

THE PRINCIPLES AND PRACTICE OF AMATEUR MECHANICAL ENGINEERING.

Lathes with Sliding Rests for metal turning, Self-acting and Screw-cutting Lathes—Drilling Machines—Planing Engines—Key-groove, Slotting and Paring Machines—Wheel-cutting and Shaping Engines, &c.

With numerous Practical Examples.

The First, Second, and Third Volumes of this work are written as accompanying books, and, originally, had one Index in common; they are intended to constitute a general and preliminary work, the addition to which of any of the subsequent volumes, will render the subject complete for the three classes of amateurs referred to in the Introductory Chapter.

Copies of the above mentioned Index for Vols. I. II. and III., are issued separately for the convenience of those who may desire to bind an Index with each of these volumes.

The Index in the revised and enlarged edition of Volume III. relates to the matter contained in that volume alone.

PAGE

CHAP. IX.—GLASS CUTTING.

CHAP. X.—LAPIDARY WORK.

REFERENCES

IN VOLUMES IV. & V. TO PREVIOUS EDITIONS OF VOLUME III. READ AS UNDER IN THE NEW.

Vol. IV.	page	17	*for*	page	1129	*read*	page	156
,,	,,	32	,,	pages	1349—1363	,,	pages	630—645
,,	,,	143	,,	fig.	1048	,,	fig.	65
,,	,,	329	,,	pages	1136—1146	,,	pages	170—176 & 203—211
,,	,,	345	,,	page	1057	,,	page	49
,,	,,	356	,,	,,	1042	,,	,,	29
,,	,,	358	,,	,,	1101	,,	,,	122
,,	,,	394	,,	pages	1072—1073	,,	pages	75—76
,,	,,	425	,,	page	1101	,,	page	122
,,	,,	470	,,	,,	1399	,,	,,	718
,,	,,	472	,,	,,	1413	,,	,,	724
Vol. V.	,,	15	,,	,,	1145	,,	,,	209
,,	,,	16	,,	fig.	1047	,,	fig.	64
,,	,,	19	,,	,,	1057	,,	,,	74
,,	,,	21	,,	page	1055	,,	page	122
,,	,,	107	,,	,,	1293	,,	,,	519
,,	,,	178	,,	fig.	1047	,,	fig.	64
,,	,,	180	,,	,,	1057	,,	,,	74

TURNING

AND

MECHANICAL MANIPULATION.

VOL. III.

ABRASIVE AND MISCELLANEOUS PROCESSES, WHICH CANNOT BE ACCOMPLISHED WITH CUTTING TOOLS.

CHAPTER I.

GENERAL REMARKS UPON ABRASIVE PROCESSES.

INTRODUCTION.

THE third volume refers to a class of operations entirely dissimilar from those which have been described in the foregoing pages; as the former descriptions and instructions have referred alone to the treatment of such materials as admit of being cut with steel tools. In page 12 of the Introduction to the first volume of this work, it is stated that—

"The third volume will be devoted to the explanation of abrasive processes; namely, those for restoring or sharpening the edges of cutting tools; those for working upon substances to which, from their hardness or crystalline structure, the cutting tools, (made of hardened and tempered steel,) are quite inapplicable; and also to the modes of polishing, which may be viewed as a delicate and extreme application of the abrasive process, and the final operation after the cutting tools, and lastly, to the ordinary modes of staining, lackering, varnishing, and other miscellaneous subjects."

In addition to the broad distinction between the processes

which have been hitherto described, and that *are* performed with cutting tools, there is another conspicuous difference, namely, that in works executed by cutting, the material is mostly removed in chips and fragments, which in the case of woods may be burned as fuel, or in metals usually admit of being reunited by fusion, and again converted into ingots, bars, or sheets, for subsequent use in the arts,—whereas in the second class of effects now to be considered, or those of abrasion by various frictional processes, the removed materials are ground to powder, and are mostly unsuited to further use.

On examination of the various abrasive processes, of which grinding for the production of form, and polishing for the production of surface, may be considered as the extremes, it will be seen there are in every case of abrasion three distinct points to be considered.

First, the substances that are to be ground or polished.

Secondly, the materials or abrasive powders by the successive employment of which different substances are polished.

Thirdly, the tools or apparatus by the agency of which abrasive substances are applied to the objects to be ground or polished.

Much variety necessarily exists under all three of these heads, and sometimes the very same substance may be referred to all of them; for example—glass is frequently polished, as in plate glass, cut glass, and lenses.—Glass is frequently used as a polishing material when pulverized and glued upon paper.—And glass is also frequently used by watchmakers and some other artizans, as a tool or rubber through the medium of which some of the polishing powders are applied to metal works in the act of polishing them.

The same thing may be observed of iron.—This metal in its various metallic forms is continually ground and polished.—An iron disc is used with diamond powder under the name of a *skive*, as the lap whereby diamonds for jewellery are polished,—and iron when reduced to the form of the peroxide or crocus, is used for very many purposes in the arts, and amongst others for polishing the specula of reflecting telescopes.

By way of condensing the numerous particulars that are to

be offered under these several heads, and rendering them easy of access and comparison, they will be arranged in alphabetical form in a " Descriptive Catalogue of the Apparatus, Materials, and Processes for Grinding and Polishing, commonly employed in the Mechanical and Useful Arts."

This will be found to contain much general information upon, and many practical examples of, abrasive processes, and will be followed by two chapters on grinding and polishing tools of all kinds; five chapters on the figuration of metal, stone and glass by abrasion, in which, under distinct sections, some of the modes of producing plane, cylindrical and conical surfaces, spheres and spherical superficies, and various mixed and arbitrary forms will be described. After which other chapters will treat, respectively, glass cutting, the art of the lapidary, gem and glass engraving and etching, the several modes in which the gem and carbonate diamond is used as a tool, and varnishing, polishing, japanning and bronzing and Oriental lacquers; the catalogue being preceded by a brief explanation of the three classes of information placed therein.

SECT. I.—PRELIMINARY OBSERVATIONS ON GRINDING AND POLISHING.

First, on the substances that are to be ground and polished.

The objects or substances the grinding and polishing of which are described, will be found to include nearly all those materials from the vegetable, animal, and mineral kingdoms which are commonly used in the mechanical arts; those especially of which mention has been made in the first volume of this work in reference to their preparation and figuration by means of cutting tools, so far as regards the substances which admit of being subsequently polished. To these will be added the cutting, grinding and polishing of various hard and crystalline bodies on which cutting tools are ineffective.

Part of these materials, such as the woods, ivory, and some of the metals and alloys, marble, glass, &c., receive dissimilar treatment from different classes of artizans, the principal variations of practice will be respectively noticed and contrasted

under their respective heads: but it will be readily imagined that many unimportant variations are made, that are based rather on prejudice than necessity, and the insertion of which would tend perhaps to confuse rather than assist, and therefore the ordinary routines will be alone adverted to.

Secondly, on the materials or abrasive powders, by the successive employment of which different substances are polished.

The grinding and polishing materials used in the arts will be found principally to consist of carbon, alumina, and silex, in various degrees of crystallization and admixture, and usually combined with the oxide of iron and some other substances as may be seen by their comparative analyses given in the annexed table.

TABLE OF THE ANALYSES OF POLISHING MATERIALS.

	Carbon.	Alumina.	Silex.	Lime.	Iron.	Authorities, &c.
(1) Diamond . . .	100·					
(2) Sapphire . . .	...	98·5	...	0·5	1·0	Klaproth.
Ruby	...	90·0	7·0	...	1·2	Chenevix.
Corundum . .	...	86·5	7·0	...	4·0	Chenevix.
Emery of Naxos	...	86·5	3·0	...	4·0	Tennant.
Emery of Jersey	...	53·83	12·66	1·66	24·66	Vauquelin.
Rottenstone . .	10·0	86·0	4·0	...	...	R. Phillips.
(3) Flint	...	0·25	98·0	0·5	0·25	Water 1·0. Klaproth.
Tripoli . . .	...	10·0	90·0	...	...	Trace of Iron and Lime.
Tripoli . . .	...	1·5	81·0	...	8·0	Water & Sulp. Acid 8·5. Bucholz.
Polishing Slate .	...	4·0	83·5	8·5	1·6	Water 9·0. Bucholz.
Polishing Slate .	...	7·0	66·5	1·25	2·5	Water 19. Magnesia 1·5. Klaproth.
Bohemian Stone	...	1·0	79·0	1·0	4·0	Water 14·0. Bucholz.
Turkey Hone .	...	3·33	72·0	13·33	...	Carbonic Acid 10·33. Holme.
Pumice Stone .	...	16·0	70·0	2·5	0·5	Potash 6·5. Water 3·0. Berthier.
(4) Oxide of Iron .	...	...	...	...	69·22	Oxygen 30·78. Berzelius.
Oxide of Tin .	...	...	...	...	...	Tin 78·34. Oxygen 21·66. J. Davy.
Chalk	...	...	...	56·5	...	Carbonic Acid 43·0. Water 0·5. Bucholz.

Carbon in its purest and most crystalline form constitutes the diamond, the hardest substance in nature; it is variously employed both in its natural and pulverized state. For instance, in the latter, in the polishing of diamonds for jewellery; in the configuration of the rubies and sapphires used for the pivot holes of watches and chronometers; in its fragments, for boring these and other minute holes, and in its natural state for their antithesis in drilling and rock-boring, for surfacing and dressing stone, and for some purposes of turning, as for granite and hardened steel. Its powder is used by the lapidary in slitting all stones, including even those which admit of being polished by abrasive powders of inferior hardness. Carbon in another of its conditions constitutes charcoal, which, and probably from the minute particles of silex disseminated throughout its substance, is employed in polishing copper and other of the softer metals.

Alumina when highly crystallized is the basis of the ruby, sapphire and other gems which are next in hardness to the diamond. This earth, with the addition of a little silex and iron, constitutes the principal part of corundum, emery, and rottenstone, abrasive materials that are largely employed in grinding and polishing the harder metals and mineral substances. Alumina, when decomposed, is the basis of most of the clays and loams, some of which, under different names, are likewise used in abrasive processes. Alumina is also the oxide of aluminium, the production and the modes of working which modern but extensively-used metal are referred to in the catalogue. It is fortunate for the mechanical arts that emery, which is nearly the hardest and most useful of all abrasive substances, is also found in sufficient abundance to serve for every required application.

Silex, in its crystalline form, and variously coloured, assumes the names of quartz, amethyst, rock crystal, flint, agate, and when in a disintegrated state, that of sand. Silex, with the addition of a little alumina and foreign matters, constitutes also the major part of the abrasive materials known as grit or grindstones, rubstones, hones and slaty stones, pumice stone, tripoli, and some others, all of which are softer than those mineral substances which are composed principally of alumina.

Of the silicious abrasives, the gritty and slaty stones are very largely employed in the formation and sharpening of tools; pumice stone, tripoli, and others for polishing metallic and other substances, softer than those which, from their superior hardness, require the employment of emery and rottenstone, abrasives that have alumina for their common base.

To those abrasive materials of which carbon, alumina, and silex form the base, may be added the oxide of iron used under the names of crocus and rouge, and the oxides of tin and lead, or putty powders, these are artificially prepared; and a few mineral substances of no great importance as abrasives are used without any preparation, such as lime and chalk.

Thirdly, on the tools or apparatus, by the agency of which abrasive substances are applied to the objects to be ground or polished.

Some of the abrasive substances are employed in the solid forms in which they are first obtained, as the grindstone, oil-stone, hones, charcoal, Dutch rush, and fish skin; some are pulverised and mixed with various cements, thus the effective hones and grindstones of the Hindoo are corundum mixed with melted shellac, and moulded into form; wax and crocus similarly mixed are used in optical work among ourselves; as also corundum, emery and sand are united with various materials to form factitious grindstones invaluable in the arts. Metal, wood, paper, leather, cloth, or bristles, are the more common implements or vehicles, by aid of which the several powders are applied in a variety of ways, after the powders have been carefully separated into grains of similar magnitude, the sizes of which must be proportioned to the perfection of the surface to be produced, and with a gradual transition from coarse to fine. This succession is adopted upon the same principle as that in filing, a coarse file is *first* used, because it may be made to act rapidly; but as the form of the work becomes gradually developed, a second cut file, a smooth, and lastly, a superfine file is used, and this *progessive* mode of action is in no case more distinctly seen in works of polishing,

than in the manufacture of a highly finished razor, which is described under the head Cutlery in the following Catalogue.

The grinding powder is always harder than the substance to be ground, whereas the implement or grinding tool is softer, and generally agrees in form with the analogous cutting or moulding tools used for producing work of corresponding shapes in other substances, as practised in different branches of the mechanical arts. Thus turned works are often polished with blunt factitious turning tools of wood supplied with the powders; flat works require artificial saws, files, and planes; a convex surface requires a concave grinding tool, and so on.

Cleanliness should be most scrupulously observed in polishing. This remark may appear misemployed as regards a process in which various dark-coloured powders, &c., are mingled with oil or water somewhat like the pigments used by artists, and are so employed that the hands must almost inevitably become more or less soiled; but that degree of care and order must at any rate be adhered to which will entirely avoid the different powders and materials becoming mixed. The finest powder, if mingled with the coarse, would be comparatively inert and harmless, but a grain or two of the coarse powders, if accidentally present along with the fine, would inflict deep scratches, and completely nullify the efforts at obtaining a highly polished surface. On this account it is desirable not only to keep the various polishing tools and powders carefully separated in boxes or bottles, but also before proceeding to each finer stage of the process, carefully to wipe or even to rinse the work in water, for the entire removal of all the previous materials employed in the earlier stages of polishing.

These preliminary and general remarks are followed by the Descriptive Catalogue above mentioned, all details of a more specific and practical character being deferred to the subsequent chapters.

SECT. II.

DESCRIPTIVE CATALOGUE

OF THE

APPARATUS, MATERIALS, AND PROCESSES

FOR

GRINDING AND POLISHING,

COMMONLY EMPLOYED

IN THE

MECHANICAL AND USEFUL ARTS.

The descriptions of the Mineral Substances are for the most part extracted or modified from those given by Phillips, Ure, Dana, and Roberts-Austen.

AGATE.—Some of the uses of Agate in the mechanical and useful arts are described in Vol. I. page 172, and this substance although much harder than Carnelian is cut and polished precisely after the same manner, the process is fully described under the head CARNELIAN in this Catalogue.

1.—The more general varieties are Ribbon Agate, a base of chalcedony interspersed with parallel layers of Carnelian, Jasper, Quartz, &c.—Moss Agate, a base of uniform colour enclosing plant-like forms of other materials, and Mocha Stone, a similar but more transparent variety. Agate is found in veins and nodules in rocky formations in Saxony and Siberia, and is imported in greater quantity from South America; large specimens of from 2 to 3 cwt. have been met with. The working of agate into beads and other small objects is in the ordinary practice of the lapidary, but these and numerous larger works for architectural and furniture decoration are differently and extensively produced at Oberstein in Germany. Natural gritstones, 6 or 7 feet in diameter by about 24 inches wide, revolve vertically at considerable speed with about one-fourth of their diameter running in a pit in the floor; two workmen to every stone lie prone upon sloping wooden beds fixed to the floor and converging, that each man may work towards his own side of the stone. The work presented near the floor is considerably below the axis of the stone, large pieces are held in the hands, smaller are cemented to the ends of sticks, the workman managing several of the latter at one time. The works are subsequently polished upon buff wheels in the ordinary manner described for the lapidary.

2.—Staining.—Ribbon Agate is seldom worked in its natural state, and affords a curious example of dyeing an apparently impervious substance. Its layers differ in porosity, the base alone generally taking the colour, whilst the denser lighter coloured layers become whiter from the heat employed. Black, most usual, is given by boiling the agate after the exterior skin has been chipped off in a solution of molasses under pressure in a steam boiler, and then in the same manner in sulphuric acid and water; blue is given by oxide of manganese, and red by salts of iron. The stones imbibe a large quantity of the fluids, and are not subsequently worked until they have *sweated* or given up the water which continues to exude for many weeks after staining.

ALABASTER.—The general modes of working Alabaster with saws, chisels, files, and turning tools, as regards its configuration, are described in pages 164-5 of the first volume, but this substance is polished quite differently by the sculptor in chiselled or carved works, by the marble worker in turned works, and by the lapidary in small objects of bijouterie and vertu, as follows:—

1.—Alabaster.—Chiselled or Sculptured Works. The dull or dead parts of sculpture, after having been carved with chisels, as more fully described under the head marble, are, 1st, smoothed with bent rasps and files, known as rifflers, and, 2ndly, scraped with a triangular scraper. 3rdly, they are additionally smoothed with fish skin or glass paper, and, 4thly, with Dutch rush used with water.

In some few instances carved works are polished, or else the ground alone from which the figures are relieved is polished by way of contrast, in such cases after the four previous stages, the parts to be polished are wrought with the end of a stick of deal or other soft wood, supplied with Trent sand and water, and used as a pencil or brush with small circular strokes, and afterwards with a stick and putty powder with water, just the same as in corresponding works of marble, which are fully treated under that head in this Catalogue.

2.—Alabaster.—Turned and Polished Works. Mr. Hall of Derby kindly furnished the author with the following outline of his usual practice. "When the article is finished with the turning tool, take, 1st, a piece of very fine soft sandstone, (found in Derbyshire in thin beds in the red marl formation,) and apply it with water to the work, whilst it is in quick revolution moving the stone all over until there is worked up a body of mud; 2ndly, take a wet rag and work this sludge well on the alabaster, then wash the work clean; and 3rdly, apply a rag charged with putty powder and water, until there is a gloss upon the work. 4thly and lastly, apply another rag charged with a mixture of putty powder and soap and water for a short time, and wipe the alabaster dry, which completes the polish."

3.—Alabaster as treated by the Lapidary.—Alabaster is far less frequently wrought by the lapidary than the sculptor, but as it is treated by the former in a manner somewhat different from the harder stones, it is made one of the three general examples of the lapidary's art, introduced into this catalogue, namely, the working of Alabaster; the working of Carnelian; and the

working of Sapphire; which substances differ greatly in hardness. To these three descriptions are appended lists of the principal stones and other substances that are similarly treated, by Mr. Ward and other lapidaries, whom the author has consulted. In the Chapter on Lapidary Work these outlines will be filled up, and the general practice of this curious and interesting art considered somewhat more at length.

In working Alabaster to the required forms the lapidary first employs as usual the slitting mill, which is a thin plate of iron fixed on a vertical spindle, and made to revolve with moderate velocity, the edge of the slicer is charged with diamond powder and lubricated with the Oil of Brick or with paraffine. This instrument, which may be considered as the circular saw for small stones, is used with light pressure and plentifully lubricated.

Secondly the alabaster is *roughed*, or roughly ground on what the lapidary terms a *roughing* or *lead mill*, namely a flat circular plate of lead, fixed on a spindle similar to that of the slicer, the mill or lap therefore travels in a horizontal plane, and is abundantly supplied with coarse emery and water by means of a brush. The stone is moved to and from the center of the rapidly revolving lap, until all the marks from the slitting mill are removed, and the stone is reduced to a flat surface.

Thirdly the alabaster is *smoothed* on the same lead mill with flour emery, but prior to smoothing the stone, the grains of the coarse emery previously used that remain on the lap are rubbed down fine with a smooth lump of emery stone. It would apparently be a better practice to use different laps for the two sizes of emery, as in the first place the operation of smoothing the mill is tedious, it also tends to wear away the lap towards the edge, thus degenerating the plane or flat surface into an irregularly coned surface, with which it is impossible to grind works accurately flat; and moreover if any coarse grains of emery are left in the lap, they greatly retard the smoothing, and consequently the polishing also. Indeed it will be found a most erroneous practice to hurry over any one process with the intention of making up for it in the next, for as each stage of the work requires successively finer polishing powders, the various steps should be continued the proportionate times, or ultimate success will be more tediously, if at all attained.

As it is difficult to polish alabaster and substances equally soft on the inelastic lead lap with rottenstone, (the means usually employed for harder stones,) the following course is generally followed. After the roughing mill has been used, the stone is smoothed on a *wood mill* or a disc of mahogany used with flour emery and water; on account of the greater elasticity of the wood mill and the slight roughness of its face from the rubbing up of the fibres, it acts more quickly and satisfactorily than the metal tool.

Fourthly the earlier stage of the polishing is accomplished on a *list mill* with pumice-stone and water, but as the list which is wound on spirally is very elastic, flat works must be lightly applied, or they will sink into the soft face of the list mill and become rounded at the edges.

Fifthly the polishing is completed on a leather lap, or a thick piece of buff leather glued securely on a wooden disc, and supplied with fine putty powder

and water. Sometimes indeed the naked hand and a little moistened putty powder are finally used for the last polish.

These several mills or laps are more particularly described under the article WHEELS in this Catalogue.

The following substances are worked by the lapidary in nearly or exactly the same manner as Alabaster, and descriptive articles are severally introduced in the Catalogue upon these particular substances, pointing out also any peculiarities of method pursued either by the lapidary or other artizan, as the case may be, in working them.

(Substances treated by the Lapidary like Alabaster.)

Amber.	Jet.	Opal.
Cannel Coal.	Lava.	Potstone.
Coral.	Malachite.	Satinstone.
Enamels.	Mother of Pearl.	Steatite.
Glass.	Nacreous Shells.	Turquoise.

4.—CLEANING ALABASTER.—Ornamental works in alabaster that have become soiled are sometimes cleaned in the following simple manner:—The object is first immersed in plain spring water for four or five days, the water is then changed and a small quantity of lime is added, the alabaster is allowed to remain in this solution for a further period of four or five days, after which it is only necessary to thoroughly rinse the object, which is allowed to dry gradually in the open air, and the process of cleaning is completed. Should the alabaster have been very much soiled, a single course of the above treatment may fail to restore the original whiteness; in this case the process is repeated, and in extreme instances a third application is sometimes necessary. Earthenware pans are the most suitable vessels to be employed, as wooden tubs, especially those of oak, are almost certain to stain the alabaster.

Objects that consist of several pieces will be separated by the above process; they are, therefore, lastly, reunited with plaster of Paris, all the parts to which the plaster is to be applied being first moistened with water to ensure its adhesion.

In the original working and finishing of the alabaster, all the pores or grain of the stone become filled with the fine powder produced in polishing, and this gives the alabaster a more compact surface than it would otherwise present. This powder is removed by the above treatment, and the alabaster then exhibits its natural granular and sparkling appearance: should this be objected to, the polish may be renewed by the employment of putty powder, applied upon a rag or stick as described in article 1.

ALBATA or BRITISH PLATE of the best kind is treated almost like silver work. In polishing spoons made of the inferior kinds of Albata, the 1st operation, which is called *roughing*, is done upon bobs, see WHEELS, article 53, covered with sea-horse hide with a plentiful supply of Trent sand and oil; 2ndly, rottenstone and oil is used; and 3dly, the finishing is done upon bobs with oil and very finely powdered lime, materials that are of the cheapest kind, and require little or no preparation.

Albata or German Silver is polished by the mathematical instrument makers, the same as Brass. See that article, paragraph 4.

ALMANDINE. *See* Garnet.

ALUMINA, in a compact or crystalline form is the base of some very hard mineral substances used in the arts, namely, emery, corundum, sapphire and ruby, of which it constitutes from 86½ to 98 per cent.: these are only exceeded in hardness by the diamond. See the table, page 4.

ALUMINIUM.—This metal, never native, is that most widely distributed throughout the earth in its oxide alumina; present in most minerals, more nearly pure and in greater quantities in alum, bauxite, clays, corundum and cryolite, from which it is principally reduced. Aluminium is white like silver, with a tinge of blue, rather more pronounced when the metal has been drawn or hammered than when cast, inodorous, and not cold to the touch, highly sonorous, and practically untarnishable and impervious to the action of gases and acids, except hydrochloric acid, by which it is dissolved, as also by strong solutions of caustic potash and soda. Specific gravity 2·55 to 2·68, according to purity, and as the metal is cast, rolled or drawn, in which remarkable quality of lightness aluminium stands first among the metals in common use, which compare as, Aluminium, 1·0; Tin and Zinc, 2·7; Iron, 2·8; Copper, 3·5; Silver, 4·0; Lead, 4·6; and Gold, 7·4. The metal is malleable, and may be rolled or drawn into as delicate sheets or wire as silver; it cuts with the chisel without cracks, and when nearly pure may be pared with the knife; hammered or drawn, it has a silky, fibrous, and when cast, a coarser and slightly irregular crystalline fracture. It is employed pure and in alloys, its recent reduction in price continually extending its applications. Chemically pure aluminium is practically unknown, that of 97 to 99 per cent. purity is considered as pure, the residue being perfectly assimilated and inseparable iron and silicon taken up from the materials and appliances used in its reduction from the oxide. Jewellery, grain weights, ornamental works stamped in relief, all kinds of small objects for personal use, foil and fine wire to replace silver for lace are among its lesser applications; the larger include vases, lamps and candelabra, table center-pieces, statuettes, &c. It has long been used for the mountings of optical instruments, and for portions of larger apparatus where light weight is a desideratum; it commences to replace copper for kitchen utensils, and has even largely supplanted tin and iron for the construction of travelling trunks; it forms valuable alloys with copper, brass, iron, steel and other metals, referred to later.

2.—Casting.—Aluminium is melted without flux; small quantities in clay or plumbago crucibles lined with a wash of two parts of quicklime to three parts of commercial hydrated oxide of alumina, mixed with water to the consistence of cream, used to prevent the aluminium taking up silicon from the crucible, heated in an open fire. In the large way, in covered iron or clay crucibles lined with charcoal, with the above mixture, or with some indifferent oxide and tar, in a closed hearth or reverberatory furnace, its fusion is slow. Fuel; coke,

wood, and sometimes gas. A dark to a cherry-red heat, rather above 1300° Fr., the actual melting point, is used; but if overheated, some of the metal adheres to the crucible, and unless allowed to cool to the proper temperature before pouring, it adheres to the sand of the moulds; in chill moulds the metal is poured rather hotter. When taken from the fire the metal is first stirred and the thin coat of oxidation skimmed from its surface; it readily fills the most delicate impressions in the moulds for small ornamental works; in larger castings the shrinkage is considerable, one quarter of an inch to the foot, hence large heads and risers are required and kept filled in pouring to exert pressure on the metal of the casting, as also unusually numerous vent holes for the escape of the gases. Aluminium containing from two to three per cent. of silicon is said to cast better than that still purer.

3.—Forging, &c.—The metal may be hammered and drawn down hot or cold. Forged cold, the purer the metal the better it behaves under the hammer; but all qualities rapidly harden and require to be frequently annealed at a temperature not exceeding 750° Fr., the absence of cracks in drawing down is one test of purity: like copper, aluminium is softened by heating, and then plunging in cold water. Forged hot, it is heated to about 840° Fr., a temperature conveniently tested by a drop or two of any mineral oil, which should roll on the hot metal as it evaporates. Cold forging gives hardness, strength, and elasticity, hot leaves the metal less soft, but otherwise approaching the qualities of cast.

Rolling.—The aluminium is either cast into slabs from which blemishes are first removed by planing or filing, or it is sheared into thinner clean pieces; these are then annealed and passed through ordinary rolls, but with more than the usual pressure. The sheets are re-annealed once or twice during their reduction, continued if they are required soft; but the final rollings are generally cold, to give hardness and elasticity. Aluminium can be rolled to less than the thickness of tissue paper, and can then be beaten as thin as gold leaf.

Drawing into wire has no peculiarities beyond those already described for other materials, Vol. I., p. 423; but the temperatures used for annealing are gradually reduced to about 212° Fr. for the finer wires, as also for the thinner sheets in rolling. As with brass, the finest wires are annealed by letting them travel above the flame of an argand burner just before they enter the draw-plate. Tubes of both round and rectangular sections are drawn upon long polished steel mandrels, from which they are easily released by the expansion of the metal when heated.

Stamping between drop-dies or in a fly-press is especially successful; thick works are raised to high relief by repeated blows, the metal annealed from time to time as it becomes too hard; thin are raised to perfect sharpness of ornament by a single blow upon sheets previously annealed, and all acquire rigidity and delicate surface finish. The best dies are of hardened steel; the upper has the design sunk in its face in intaglio, and a second similar die with a reproduction of the intaglio just sufficiently smaller in its depths and widths throughout to allow for the thickness of the sheet of aluminium, is prepared and forcibly

stamped into a white hot block of steel to produce the relief lower die. Cast-iron dies are used for inferior works; for these a plaster cast taken from a relief model of the design, is pressed into the sand mould to give the intaglio in the face of the upper die, and a relief taken from the plaster cast first named and partially rubbed down, gives a reduced intaglio in the mould for the relief on the lower die.

4.—TURNING.—Pure aluminium turns very readily, hammered or drawn better than the cast metal. All is rather apt to drag or tear, and it is always difficult to avoid leaving marks of the tool, which, even when they cannot be felt with the finger nail, are still visible on the smoothest turned surfaces as small inequalities of texture. Narrow-edged tools ground to cutting angles from 50° to 60°, preferably used in the slide rest, remove long curled shavings; a succession of light cuts diminishes the tendency to tear, finishing cuts should be of quite inconsiderable depth, the tool lubricated with oil, turpentine or milk. The author succeeds best with a triangular blade cutter-bar, the front angular edge rounded away to a width of about one-sixteenth of an inch, cutting angle 50° and angle of relief about 8°; this, lubricated throughout with milk, produces an excellent delicately fine surface on cast aluminium. The turning is far better when the metal is even but slightly alloyed; a series of cast samples, ranging from 95 to 91 per cent. aluminium, alloyed with combinations of tin, nickel, copper, zinc and cadmium, which scarcely differed in colour or character from pure aluminium, kindly placed at the author's disposal for experiment by Mr. A. Magnus of the Phœnix Aluminium Co., London, turned with the same tool as that used for pure cast aluminium, all worked with more facility and gave distinctly better results. Sheet aluminium may be spun in the lathe with the smooth blunt-ended burnishers, as described for spinning other ductile metals and alloys, Vol. I., Chap. XIX.

5.—POLISHING, &c.—The marks left from the file or turning tool, when deep, may be removed by rubbing with the flat face of a piece of pumice-stone, or with charcoal, both used with water; the latter leaves finer scratches. The work is more generally smoothed from the tool with two sizes of fine emery, followed by flour emery, all used with oil, and finished with washed whiting, or, better, with putty powder, and, if used with the necessary precautions, these leave the surface of a very fine equal grain. The same powders used with water give a dead white surface of a frosted character. The grinding and polishing materials may be applied on smooth rectangular pieces of beech or other equally hard wood, 2 to 3 inches long, held flat on the work in the fingers with little pressure and traversed and twisted about in all directions just as in French polishing; or on buff sticks, or in the form of emery paper wrapped round a file. The softness of the metal is a difficulty; the surface produced by each powder should be perfectly uniform in grain before using the next; every trace of each must be absolutely removed, as a single grain of a former will at once produce a scratch, frequently rendering it necessary to go back a stage in the polishing for its removal; an accumulation of any one powder will also produce irregular marks, hence it is better practice to spread the powders always in but moderate quantity, evenly on the polishers under the finger,

instead of placing them directly on the work. Towards the conclusion the emery paper or the powders on the rubbers are worked until nearly if not quite dry, and until they become thoroughly clogged with the metallic dust they remove from the work, the dust from the aluminium gradually reduces the activity of the polishers, and its friction appears to improve the final surface. Great advantage is found in washing all the powders to ensure their equality in size, see EMERY, articles 2—4, a precaution absolutely essential with the whiting, which invariably contains sand or grit that must be separated. The polish on aluminium is rather a very fine and delicately even grain than lustrous, but a lustre is given by burnishing, conducted in the manner described under the head of BURNISHER, article 2, the steel or stone burnisher lubricated with an emulsion of equal parts of olive oil and rum shaken together in a bottle.

MATTING, employed on decorative objects, leaves portions or the entire surface a frosted, pure, dead white. The work is first smoothed with emery, or left untouched if stamped, and is then cleansed from all oil with benzine or dry whiting. 2ndly, it is plunged and moved about for a few moments in a strong solution of caustic soda, which slightly dissolves and roughens its surface, immediately after it is well washed in clean water. 3rdly, it is dipped in a mixture of two parts of nitric to one of sulphuric acid, again washed in water, and dried in clean sawdust.

6.—SOLDERING pure aluminium is not yet easy, the metal shows disinclination to combine with the solder, and the edges of sheets are liable to melt away from it. The soft solder most used is composed of aluminium 6, copper 4, and zinc 90 parts, and the hard of 9, 6 and 85 parts of the same metals; another contains Al. 5, bismuth 5, and tin 90 parts. The soldering bit is of aluminium, if of copper it colours the metal; the solder is laid on in small grains like spelter, usually without flux, and the heat is generally applied with some form of blowpipe jet worked by the foot, by an assistant, or by power, that the operator may have both hands at liberty. Whenever possible, the pieces are rubbed together so soon as the solder melts, otherwise the joint is made by rubbing with the bit; sheets with lap joints are more successful in holding the solder, and those which can have their edges electroplated with copper are readily joined, provided the heat be not in excess. The melting together of pure aluminium by the system of autogenous soldering, described Vol. I., p. 452, is also successfully practised. Aluminium and copper alloys are soldered without difficulty.

Mr. Magnus, a high authority, has favoured the writer with his experience in soldering aluminium. He says, "The difficulties arise from the circumstance that heated aluminium exposed to the air is immediately covered with an imperceptible film of oxide, which suffices to prevent the solder and the metal from arriving in metallic contact. Various fluxes, and some simple substances, such as paraffine, wax, &c., have been tried to prevent the formation or to remove this film, as yet with but little success; chloride of silver is perhaps the best, but its melting point is so near that of aluminium that it cannot be used for sheets. Mr. T. W. Richards added a small percentage of phosphorus

to the solder to deoxidize the aluminium, this nearly always gives good results; the same may be said of Wegner and Guhr's flux, composed of stearic acid 80, chloride of zinc 10, and chloride of tin 10 parts. Success does not depend so much on the use of any particular solder or flux as on the perfection with which the parts to be joined are first coated with the melted solder, which must be well rubbed on with an aluminium or nickel bit until the film of oxide is destroyed and the solder has uniformly united with the aluminium. The temperature is as important, it must be sufficient to melt the solder and to alloy it with the aluminium, and yet not high enough to melt the latter, nor even to bring it to its pasty condition, which is reached long before its melting point. With care in these respects, good strong joints that will withstand hammering are obtained with Bourbouze's solder of 45 parts tin to 10 aluminium; while for soft solders the proportion of aluminium may be reduced by one half. With the addition of 2 or 3 parts bismuth to the last named, the solder melts at a lower temperature and runs better, but is rather brittle.

"A strong hard solder, but which requires a high temperature, is composed of zinc 85·5, aluminium 7, cadmium 3, silver 3, and copper 1·5; and Wegner and Guhr's solder, tin 80 to zinc 20, used with the flux already mentioned, when not overheated gives a good joint but somewhat dark in colour. Richards' patent soft solder, tin 32, zinc 8, aluminium 1, and phosphor-tin (containing 5 per cent. phosphorus) 1 part, as also another soft solder composed of tin 45, cadmium 10, aluminium 8, and bismuth 4 parts, are used without flux, and give good results."

7.—Aluminium is alloyed in varied proportions with copper and with copper and zinc, known as aluminium bronze and aluminium brass, with iron and steel, and with many other metals. The bronze is produced in great and increasing quantities, and in this it may be said that aluminium finds a wider utility than in its pure state. Aluminium increases the fluidity of the molten metals, the soundness of the castings, and, largely, the hardness, elasticity and tensile strength of the alloys; reduced sections and weight are therefore also generally possible in the forms worked from them, and the alloys have a greater resistance to corrosion from the atmosphere or gases, sea-water and most acids.

Aluminium Bronze usually contains from 5 to 20 per cent. of aluminium, and varies accordingly in colour from that of red, through yellow gold, to a whiter greenish yellow; the colour of copper with 5 per cent. of aluminium is exactly that of gold. For its preparation the copper is melted in plumbago crucibles with cryolite as a flux, and the requisite proportion of aluminium broken into small pieces, gripped in iron tongs, is thrust and held in its midst until dissolved, the first additions causing a considerable rise of temperature in the copper; the mass is then well stirred with an iron rod and poured into bars; these are then broken into pieces, remelted, stirred and recast, several remeltings being necessary to ensure uniform incorporation. This process is followed to obtain exact mixtures; for which also it is usual to add rather an excess of aluminium, and then, after analysis of the resulting alloy, the further quantity of copper required to give the precise percentage. Commercial aluminium bronzes are now generally compounded concurrently with the

original reduction of the alumina by processes referred to Article 8. The patterns and moulds for castings require similar precautions as for pure aluminium, heated moulds are preferred, and all castings are cooled slowly. Al. bronze may be forged, stamped or rolled at a dull to a cherry red heat, the lowest temperature that will suffice for any given specimen is preferred, and it gains in tenacity and elasticity; any but light cold hammering, especially with those richest in aluminium, is avoided as likely to produce cracks. Cold rolling gives a spring-like character, but the sheets have to be frequently annealed and then dipped in sulphuric acid and water to remove any oxide or deposit from the fire throughout the process. The bronzes are softened like copper by heating and cooling in water; they are worked and polished like gun metal and are readily soldered.

As regards the colours of aluminium alloys, it may be added that the experiments of Professor Roberts-Austen have brought out the curious fact, that gold combined with about 25 per cent. of pure aluminium yields an alloy of a beautiful rose-pink, a colour hitherto unknown in metallurgy; this alloy although of rather a crystalline character should have a future for ornament in jewellery.

ALUMINIUM BRASS.—An addition of from half to four per cent. is made to ordinary molten brass as the alloy is to be hard or soft; as a rule the larger the proportion of zinc, the less aluminium, 30 per cent. has 2 to 4 per cent. aluminium and 40 per cent. zinc but 2 or less. The brass acquires increased strength, toughness and ductility, relatively more than in the similar case of copper; the alloys oxidize but less than ordinary brass. In its preparation the copper and zinc are first melted together and then the aluminium added in the same way as for bronze; for small percentages the addition is made in the form of pieces of rich aluminium bronze. The alloy runs freely, but the same precautions are observed in casting as for bronze. The richer aluminium brass may be forged, stamped or rolled at a dull red heat, the less at lower temperatures and that of 1 per cent. and under is hammered cold. These alloys are otherwise worked and polished like ordinary brass.

FERRO-ALUMINIUM.—A minute percentage of aluminium added to molten iron or steel combines with and eliminates all carbonic oxide from the mass, beyond which remarkable chemical action, it instantly lowers the melting points and considerably increases the fluidity, the metals run more freely in the moulds, cease to give off gas bubbles and yield sounder castings. The value of this addition is still considered an open question, but many steel manufacturers now add from ½ to 1 per cent. of aluminium in pieces of alloys of 10 to 15 per cent. of pure aluminium and iron or steel; the red-hot bits of alloy are generally added to the molten steel when in the ladle, held beneath the surface to dissolve and then the mass well stirred with iron rods before pouring. Increased liquefaction is still more marked with wrought iron, which latter when heated to its melting point still remains in a semi-fluid pasty condition until superheated, by which it is deteriorated. It was discovered by Mr. Wittenstroem of Stockholm in 1883, that one per cent. of aluminium added at the pasty condition at once causes complete fluidity, which the iron then

retains throughout the subsequent pourings. The name of Mitis metal, signifying flexible and ductile, has been given to iron thus treated, which acquires much of the character of steel, is homogeneous, malleable, and produces excellent castings; it is supplied commercially.

8.—The origin and the late rapid progress in the production of aluminium is so interesting as to permit the following, compiled from the writings of Deville, Richards, Minet and other authorities. The suggestion of a metallic base of alumina is attributed to Marggraff so early as 1754; a little later Moveau experimented on its reduction from alum, and subsequently Lavoisier named it aluminium. In the first decade of this century Davy and others attempted the reduction by the voltaic pile and by potassium, and Oerstadt in 1824 was nearer success with potassium and mercury amalgam. Wöhler in 1827 obtained a grey metallic powder by decomposing chloride of alumina by potassium, and in 1845 his researches first produced fusible and malleable aluminium in bright metallic globules.

Until about 1854, aluminium, potassium and sodium, it may be said, were still metallic rarities, but at this date M. H. St. Claire Deville, by labours based upon those of Wöhler had reached a point giving promise of aluminium in quantities sufficient for it to rank among the useful metals. The Institut de France then voted him a sum of money for further experiments, and in the following year he commenced production on a small commercial scale, the Emperor Napoleon III. personally providing the necessary funds. His attempts at reduction by electrolysis were unsuccessful, and the first process employed, the reduction of alumina chloride by potassium under high temperature, was objectionable from the risks and the excessive cost of the potassium, at that time about 90*s*. per pound. Aluminium was nevertheless produced in fair quantities although at a prohibitory price, and in a paper read before the Academy, Paris, June 1855, M. Deville, after gracefully acknowledging the scientific and other assistance he had received, concluded: "I hope to have placed the aluminium industry upon a firm basis"—an aspiration completely realized.

Sodium, more efficacious and less dangerous, was yet more costly than potassium, and it required a proportion of three pounds of sodium to produce one of aluminium, hence M. Deville, aided by M. Debray, next essayed its economical commercial production, and finally in 1887 reduced its cost to about 10*s*. the pound; experiments with similar aim as to the chloride of alumina also proved the value of the argillaceous minerals bauxite and cryolite, and aluminium was then produced in larger quantities, its price, about 80*s*. the pound, alone retarding its applications. From this date numerous Works were established in France and on the Continent, in England and America, to carry on Deville's process, and although modifications were made in details and the cost of materials was gradually reduced, his process remained virtually unaltered until 1886.

Comprehensive changes then took place, including a large reduction in the cost of the chloride effected by Mr. James Webster in 1882, and the cheap and safe production of sodium in large quantities from a mixture of fused

caustic soda and carbide of iron, effecting a saving of about 75 per cent. upon its previous cost, patented by Mr. H. Y. Castner of New York, together with his modifications in the method and plant for the reduction of the chloride by the sodium.

The Deville-Castner process, using Webster's preparation of the chloride, was carried on at extensive works erected at Oldbury, Birmingham, and since elsewhere. The alumina chloride mixed with charcoal and common salt and dried in small blocks, is distilled and the vapour passed into large receptacles charged with chlorine gas, where it condenses into a deliquescent substance; this with a proportion of cryolite and metallic sodium in small pieces is mixed in revolving drums from which it falls into a reverberatory furnace whence after from three to five hours the metallic aluminium is run off, re-melted in plumbago crucibles and cast into ingots. The metal of about 98 per cent. purity was at first produced at about 20*s*. the pound, a cost since considerably reduced.

According to Mr. Anderson the reaction in this process is represented by the formula $2(NaCl)Al_2Cl_3 + 3Na_2 = 8NaCl + 2Al_2$, in other words, one molecule of double chloride of alumina and three of sodium yield eight molecules of common salt and one of aluminium. The Oldbury plant is of stupendous proportions, manufacturing most of the materials and capable of yielding one and a half tons of aluminium per week, and to give some idea of the scale of operations, he says—22,400 lbs. of the double chloride, 8,000 lbs. of cryolite, 6,300 lbs. of metallic sodium, and 8 tons of coal are consumed for every ton of aluminium produced. To produce these materials there is required,—for the double chloride—common salt 8,000 lbs., alumina hydrate 11,000 lbs., chlorine gas 15,000 lbs., and coal 180 tons;—for the sodium metal—caustic soda 44,000 lbs., carbide of iron, pulverized iron 1,000 lbs., pitch 12,000 lbs., and coal 75 tons; and for the chlorine gas—hydrochloric acid 180,000 lbs., limestone dust 15,000 lbs., lime 30,000 lbs., and manganese, the greater part of which is recovered, a loss of 1,000 lbs.

In the same year, 1886, Works were established near Newcastle to carry out the processes of Professor Curt Netto of Dresden, for the manufacture of sodium and its use in the reduction of aluminium from cryolite. Melted caustic soda dropping by small quantities into retorts charged with incandescent charcoal sublimates and its condensation, when deprived of its carbon, is solidified on perforated round plates on the ends of long iron rods. For the reduction, cryolite and chloride of sodium are melted together and the proportion of metallic sodium on the rod is pressed down to the bottom of the crucible, the operators protected by iron barred masks; the sodium instantly dissolves, streams upwards through the cryolite and the reaction is complete. The contents of the crucible are at once poured into iron pots, where the aluminium collects at the bottom. The reduction is otherwise effected without danger in a heated iron cylinder, mounted on trunnions and provided with screw plugged openings in its closed ends; the cryolite charge melted, the sodium is introduced, the aperture stopped and the cylinder rotated to aid the reaction, with the cylinder again vertical the contents are run off into the cooling pots.

The earlier attempts at electrolysis failed mainly from the insufficiency of battery power, a condition entirely changed by the invention of the dynamo, since when, very many methods of electrolytic reduction have been practically tried both for pure aluminium and for the direct production of its alloys; some of which processes are in extensive and constantly increasing use.

In Cowles' process, first applied in America 1885, corundum mixed with about half its weight of charcoal and the proportion of granulated copper, is placed in a closed fire-brick rectangular box lined with a cement of powdered charcoal and lime. The carbon electrodes of the current from opposite ends of the box,—three inches diameter by thirty inches long for a small, or several such carbons bound together for the larger furnaces,—have their ends close together and are gradually separated as the mixture lying between them melts, until the arc traverses the whole mass then at intense heat and fluid. The contents after three to five hours of this action are allowed to cool and are withdrawn on the removal of the luted down cover, which latter is perforated for the escape of some part of the gases; the alloy contains from 10 to sometimes 40 per cent. of aluminium, after analysis further copper is added on remelting to give the bronze the desired percentage. The process is also carried out on a large scale at Stoke-upon-Trent, and the contained aluminium costs about 6*s*. the pound.

By the process of M. P. Heroult of Paris, 1887, operated in France and at Neuhausen, Switzerland, large quantities of pure aluminium are reduced from alumina, cryolite and sodium in receptacles built of carbon slabs closely contained by others of plumbago; the carbon box acts as the cathode and the anode, a carbon slab, passes through a stuffing box filled with loam in the luted down cover of the furnace. For bronze alloys a charge of pure copper is first melted by the arc, the carbon electrode is then raised just out of contact with the fused copper, which latter from its contact with the furnace then becomes the cathode and the alumina is fed in. The process is continuous, the alloy being tapped out from the base of the furnace at regular intervals and fresh supplies of copper and alumina added through apertures temporarily opened in the cover; the alloys are reduced to their percentage by remelting with additional copper, and the contained aluminium is said to be produced at a cost of about 4*s*. the pound.

M. Adolphe Minet's process, first established in Paris, 1887, and now carried on at St. Michel, France, and that of Mr. Hall patented in America, 1886, and worked at Pittsburg, U.S.A., 1888, and since at Patricroft, Manchester, differ in details, but both electrolyse in a bath of fused aluminium and other salts. In Hall's method the bath is composed of fluorides of calcium, sodium and aluminium contained in an iron crucible lined with carbon which is the cathode, the anode consists of six to ten of the large carbon rods bound together, as already mentioned, suspended vertically in its midst; the bath melted by the current, moderate supplies of hydrate of alumina are constantly added, and the metallic aluminium of 94° to 98° purity sinks and is dipped out from the bottom of the bath every two or three days. For alloys the bath contains salts of barium; the copper first

melted by the current acts as the cathode, and the aluminium reduced from its hydrate as before combines with it. Minet's process electrolyses chloride of sodium and fluoride of aluminium in an iron receptacle encased in fire-brick and provided with a tap hole at the base. The carbon electrodes stand vertically in the bath with the lower end of the negative within a cup, the enlarged inner end of the tap hole; the fluoride is continually replenished in the form of cryolite and the pure aluminium reduced from it collects on and drips from the end of the cathode into the cup from which it is run off without interrupting the process. For alloys the crucible is of copper or iron as one or other of these metals is to be used for the alloy, and is the cathode; the anode may be carbon or of the one or other metal respectively. The current causes the aluminium to deposit on the sides of the crucible, as it thickens it is melted off by the heat of the bath, falls and mixes with the molten iron or copper which when sufficiently enriched is tapped off from below; analysis and remelting with further copper or iron follows as usual.

Finally it may be noted that the continual advance in the manufacture of pure aluminium since its introduction among the useful metals in 1885, has reduced the cost from about 90*s*. to less than 4*s*. the pound at the present time, and, there is little doubt, that the cost will be yet diminished. The elegant colossal figure of Eros which surmounts the Shaftesbury Memorial in Piccadilly Circus, London, is cast in pure aluminium.

AMBER after having been filed may be polished 1st with Trent sand, or scraped Flanders brick on flannel with water; 2ndly, rottenstone with oil on flannel; 3rdly, rottenstone dry on the hand.

Turned works are generally polished first with glass paper, and then with rottenstone and oil. The makers of amber beads and mouthpieces for pipes turn, file and scrape the material to shape and then polish, 1st with pumice stone powder, 2nd with yellow tripoli, and lastly with Calsh, which see, all moistened with water and applied on revolving wood discs covered with thick flannel and also on folded flannel and linen rag.

The lapidary works amber after the mode described under Alabaster, article 3, but necklaces and other ornaments in amber that are cut into facets, are more usually and better executed by the gold cutters, or those artizans who cut and polish facetted works, and by the same routine as that described in the article 3, under the head GOLD.

Turned, cut and polished amber is generally transparent and of a brilliant sherry colour, an opaque variety called *fat* amber is pale lemon colour, the two frequently combine in a marbled or mottled variety; it is said that the natural uniform opaque colour may be given to clear amber by melting that with heat. Amber is found on the coasts of the Baltic and dug in peat-like deposits in a few places inland in Germany; it is imported in small irregular pieces seldom exceeding about 4 inches long or 1½ inches in width or thickness, the largest weighing about 3 oz., and a great proportion are flawed. A block weighing 8 lbs. and without perceptible flaw was exhibited in Dantzig in 1885, and another weighing 13 lbs., but disfigured by blemishes, is among the specimen

in the Mineralogical Museum at Berlin. Fictitious amber is made from gum copal, and some specimens have much of the appearance and some of the qualities of amber; it is also successfully imitated in all its varieties in the artificial material Xylonite, noticed in this Catalogue.

Amber varnish is made by melting amber in oil and other solvents in the manner described in Chapter VII.; it is notable as the varnish on the violins of the old masters and is still in moderate use.

AMETHYST or violet quartz is cut and polished by the lapidary like Carnelian, which see.

AQUAMARINE, called also Beryl, and Ancient Beryl, is of various shades of pale yellow, green and blue; it was so named from its resemblance to sea water, and is worked like Carnelian.

ARKANSAS OILSTONE.—*See* Oilstone.

ASTERIA.—*See* Sapphire.

AVANTURINE, a mineral which is found variously coloured and always enclosing particles of mica; the most common colour of the base is brown or reddish brown. It is worked by the lapidary like Carnelian, but does not admit of so good a polish as the imitation.

2.—Factitious Avanturine, which is glass or paste enclosing particles of metal is generally more close and brilliant than the real stone, and was much used in common jewellery, the imitation avanturine is cut and polished like other pastes, as described under the head Alabaster, article 3. The method of making this artificial avanturine which is now lost, is considered to have originated with the Italian artists, this substance is now very scarce and much valued.

3.—Artificial Avanturine, which is more brilliant than the last, and used as a microscopic object, is prepared from blue glass coloured by the oxide of copper, which is stirred with an iron rod. The oxygen from its superior affinity for the latter metal quits the copper, and unites itself to the iron, and in the act of resuming the metallic form, the copper partially crystallizes, and becomes entangled in the glass. From the striated condition the glass assumes on being stirred, the bright and metallic picture is irregular, and appears full of hills and dales, occasionally clouded with the dark coloured glass in which no copper is visible. The crystallization may be distinctly seen with a common lens of half an inch focus.

BATH BRICK.—*See* Flanders Brick.

BEES WAX.—*See* Wax.

BERYL, a term that designates amongst lapidaries and virtuosi a very rich deep brown diaphanous carnelian; it is frequently engraved into intaglios, just after the manner of carnelian generally.

BETEL-NUTS, when turned, are in general polished only with fine glass paper, and a few of their own shavings; whiting and water may be used as for Ivory.

BILLIARD BALLS.—*See* SPHERES, article 2.

BLOODSTONE is a very hard, compact variety of hæmatite iron ore, which when reduced to a suitable form, fixed into a handle, and well polished, forms the best description of burnisher for producing a higher lustre on gold leaf, silver and on gilt coat-buttons, the last performed in the turning lathe. The gold on china ware is burnished by its means. Burnishers are likewise formed of agate and flint; the former substance is preferred by bookbinders, and the latter for gilding on wood, as picture-frames, &c.

BLOODSTONE, the appellation sometimes employed by the lapidary and jeweller, to distinguish a dark green stone usually containing red spots, whence its popular name of bloodstone; it is mineralogically known as the Heliotrope, and is considered as a variety of chalcedony: this stone is worked exactly like CARNELIAN, but is much harder and takes longer to polish.

BOB, a familiar name used at Birmingham for small leather polishing wheels with rounded edges, each made entirely of a thick piece of *bull-neck*, or sea-cow leather, perforated to receive the spindle, and used in polishing the insides of the bowls of spoons and other articles. See WHEELS, article 54.

BONE.—After the turning tool, file or scraper has been used, bone is polished, 1st, with glass paper, 2ndly, with Trent sand or Flanders' brick with water on flannel; 3rdly, whiting and water on woollen rag; 4thly, a small quantity of white wax is rubbed on the work with a very quick motion, the wax fills the minute pores, but only a very small quantity should be allowed to remain on the work. Common bone works, such as nail and tooth-brushes, are frequently polished only with slaked lime used wet on flannel or woollen cloth.

BOULDERING STONE.—This name is applied by the Sheffield cutlers to the smooth translucent flint pebbles, found in gravel pits, with which they smooth down the faces of buff and wooden wheels, by abrading any large grains of emery or other powder contained on their surfaces. See WHEELS, articles 45, 46. The bouldering stones are usually selected of about the size of a hen's or pigeon's egg, and of a flattened form; and the flat side becomes gradually worn down and smooth from its continual application. The term appears to be derived from the provincial use of the word *boulder*, to denote the round stones used in paving; whence, also, boulder-setter or pavior.

Metal laps are "*bouldered down;*" first, they are supplied with a little emery and oil, which is spread with the fingers and then pressed into the metal and worn down fine and smooth with the *bouldering stone;* wood laps are first anointed with flour emery or fine flour emery, they are then well *bouldered*, and are lastly waxed by holding a small piece of wax against the revolving wheel; these processes greatly reduce the cut of the powders; and

unless the bouldering stone is plentifully applied the *colour* or high gloss cannot be produced on the works.

BRASS is finished by different classes of artizans by methods that are widely dissimilar, many of which are described; and it may be considered that the same modes are also suited to the other alloys, consisting principally of copper, such as gun metal, aluminium bronze, electrum, or German silver, &c., particularly as regards parts of machinery and mathematical instruments.

1.—TURNED WORKS IN BRASS are frequently polished with emery paper alone, two sizes of which are mostly used with a little oil. For plane and cylindrical surfaces, the emery paper is wrapped around a parallel piece of stick, and for internal plane surfaces it is applied by means of a small cubical block of wood; these methods tend to preserve the external angles from being rounded. An additional lustre is given, if required, by woollen cloths with oil and rottenstone. When the work is not to be varnished, a minute quantity of the polishing oil is left on, which somewhat prevents tarnishing.

The sliding tubes of telescopes after having been cleaned off with fine emery paper, are brushed with a revolving or wheel brush with fine crocus and oil, and are finished with a woollen rag and rottenstone, nearly free from oil, and rubbed lengthways, the lathe being for the time at rest.

2.—COMMON FLAT WORKS, after they have been filed up, are frequently finished first with coarse and then with fine emery paper, which is often used dry or without oil and wrapped around a file or wooden rubber. The grain is usually laid straight, or in one direction; at other times the works are coarsely curled by a circulating motion of the hand.

3.—SUPERIOR FLAT WORKS.—The brass plates for the mechanism of harps are perhaps more carefully treated than any of this kind. The plates of the harp machinery are planed and scraped, the mechanism is then fitted, and the second axes or arbors are ground into their respective pivot-holes with fine oilstone powder. The plates are again carefully scraped, after which they are polished, 1st, with charcoal in the stick, to remove all the marks made with the scraper and file. 2ndly, flour emery is dusted over the plate from a muslin bag, and rubbed with a piece of wood three or four inches square, covered with baize nailed around the edges, to serve as a rubber. 3rdly, rottenstone is similarly employed upon a rubber covered with two or three thicknesses of fine woollen cloth; the plate is then washed quite clean and dried. 4thly, it is finished with a dry buff rubber and rottenstone; the holes are then cleaned out with a feather slightly coated with dry whiting, and finally the plate is varnished. In all the processes it is necessary to follow the curvature of the plate, in order to lay the grain in accordance therewith.

Brass door-plates of the best kind are treated with nearly the same care, although immaterial variations are often made in the routine.

4.—FLAT WORKS IN MATHEMATICAL INSTRUMENTS.—Such of these as are in brass and gun metal, when left from a very smooth file, are prepared first with a stick of water of ayr stone; and are afterwards finished with water of

ayr stone scraped to a fine powder, mixed with a little oil to the consistence of treacle, and applied with a smooth piece of white deal. If the work present lines from the grain of the wood, it is rubbed with the clean finger, or a buff stick smeared with oil, the polishing stuff that remains on the work being sufficient for the concluding step.

The edges of work, after having been drawfiled, are scraped with a sharp triangular scraper, applied almost without pressure in order to avoid utters or indentations; oilstone powder with oil is next used on a piece of mahogany, then scraped water of ayr stone, as above, and lastly, a buff stick with dry rottenstone.

5.—Flat Works Curled.—These are filed, scraped, and stoned, as by the mathematical instrument makers. The work is then clouded with a piece of charcoal and water, by means of which the entire surface is covered with large curly marks, which form the ground. The curls resemble an irregular cycloidal pattern, with loops of from one-quarter to one inch diameter, according to the magnitude of the work. Similar, but much smaller marks are then made with a piece of snakestone, bluestone, or even common slate pencil, filed to a blunt point. The general effect of the work much depends upon the entire surface being uniformly covered, with which view the curls should be first regularly continued around the margin, the central parts are then filled in; after which the work is ready to be varnished.

The curled surfaces are desirable, in so much as any little accidental injuries or rubbing, arising from the continued use of the articles, are less observable upon curled surfaces than upon similar pieces laid with an even grain; and the curled parts mixed with the bright edges have a good effect. The mode was introduced by the late J. J. Holtzapffel.

6.—Watchwork in Brass.—Flat works of medium character, after having been filed, are polished, 1st, with a stick of bluestone and water, and 2ndly, with a slip of box wood, with the unguent obtained by rubbing two pieces of bluestone together with oil. The best and flattest watchworks, after 1st, the bluestone, are polished 2ndly with pewter and red stuff or crocus, and 3rdly with a piece of tortoiseshell, horn, or ivory, supplied with very fine red stuff and oil.

Tortoiseshell is preferred for the polisher, as it may be used nearly dry and leaves the fewest streaks or shades in the work; horn is next in estimation, and ivory the least of the three; each of these materials, as also pewter, glass, &c., is used in flat pieces from one to two inches square, which are smeared with the powders mixed with oil; the work is then rubbed on the surface with the fingers, as if it were the muller used in grinding paint; this produces very flat surfaces. The burnisher is sometimes used after the powders.

Most of the brass work of watches is gilt by water gilding, to prevent it tarnishing from the effect of the atmosphere. The polishing of the steel part of watchwork is described under the head Machinery in iron and steel in this catalogue, article 13.

7.—Braziers' Works.—The coppersmiths and braziers adopt nearly the same

treatment for brass as for copper. Subsequently to the brass work having been annealed for the last time, and before it is planished with the hammer, it is generally pickled with nitrous acid diluted with very little water, and then scoured with coarse red tripoli and water to remove the oxidation caused by the fire. The work when planished is cleaned 1st with crocus and oil; 2ndly, the oil is rubbed off with whiting; and 3rdly the final polish is given with dry rottenstone usually applied on an old worsted stocking.

8.—Stamped Works in Brass, for house furniture, such as finger plates for doors, and numerous other objects stamped out of sheet brass, are treated in a manner entirely different from all the preceding, as the sheet brass when carefully rolled is left very smooth and only requires to be made bright. The stamped works are 1st cut out, 2ndly figured between dies, in a fly press, or under a stamp hammer usually called a force, 3rdly they are annealed, 4thly coloured by immersion in an acid preparation, 5thly washed and dried in saw-dust. The entire surface is now of a rich yellow or gold colour but dead or dull, 6thly the parts desired to be bright are burnished with a steel burnisher which is lubricated with water alone, or with water having a trifling admixture of vinegar or beer, and 7thly the work is varnished. The methods of colouring, bronzing, and varnishing stamped works and others of the same character will be hereafter detailed.

9.—Cast Works in Brass for House Furniture, including lamp and gas fittings. These works receive little or no polishing by the ordinary methods of abrasion with powders, which would be too tedious and expensive a process. The smallest and commonest of the castings, after having been cleaned by the brass founder, in the rumble, are coarsely filed and then scraped; some works are cleaned and shaped on endless band emery grinders, see Emery, article 13, and *idem*, Chapter IV.; those pieces which are more carefully moulded, as described under *fine casting*, Vol. I. p. 341, require only the removal of the rough edges or burrs, and the tubes employed in gas fittings, &c., are left sufficiently smooth from the draw-plate. The several parts after having been adapted together, by aid of the file, turning tool, screws or solder, are almost exclusively decorated by the processes of dipping, bronzing, burnishing and varnishing; most of which processes, as noticed in the last article, will be treated of towards the end of this volume.

BRICK OIL, or Oil of Brick, dark olive in colour, opaque and of pungent odour, a lubricant used to moisten the drills, slicers, polishing mills and tools of the lapidary and seal engraver, prepared from pure olive oil as follows: Clean small fragments of old common red bricks are made red hot and slacked in the oil, the pieces of saturated brick are then placed in a retort and the oil distilled over; the process appears to deprive the olive oil of some of its constituents and to render it less oxidable. It is prepared by some operative chemists and purchased by the lapidaries.

Mr. Batson says,—brick oil gums or clogs far less than the crude oil, an important point in slitting and in boring in which the tool is enclosed within the stone, but it is comparatively expensive. Hence it is the custom to use it in

two saucers, one from which small quantities of the oil are taken and dropped on the work, and the other is placed below the revolving slicer to catch all that drips from the work and hand; and, when the powder of the slit stone has settled in the form of mud, the supernatant oil is poured off and used again. He also says,—brick oil is now much less used and is generally replaced by common paraffine which is found to answer equally well by both lapidaries and seal engravers; the low cost of the paraffine oil also allows more plentiful lubrication.

BRISTLES.—The strong spring-like hair of swine of the domestic and wild varieties; colours, white, brown, gray to black, the longest and stiffest bristles coming from the crest, spine, and shoulders of the animal. Extensively used in handicrafts for polishing brushes and wheels of various grades of hardness, the differences obtained, first, by the selection of bristles of different strength, and next, by shearing the tufts of the hair when inserted in the wood backs to shorter lengths according to the stiffness required. Still more largely used for all kinds of brushes; white bristles carefully cleaned and bleached, prepared principally in France and known as *beau blanc*, are used for nail and tooth brushes and for artists' hog-hair brushes; the longer coarse bristles are selected for the use of harness and shoemakers to point the ends of their waxed threads for sewing and command a high price. Wheel bristle brushes, some of large size containing from 56 to 84 lbs. of bristles, are used in the manufacture of cloth.

Mr. James Matthew says,—"Like all hair the bristle grows from a sheath or follicle in the skin, the butt end is called the *root*, the other extremity splits into two or three divisions and is technically called the *flag*. Our main supply comes from Russia; the bristles collected by dealers in the interior, roughly cleaned and sorted and tied up by the roots in weak bundles with bands of the inner bark of the birch tree, are packed in casks and exported solely from St. Petersburg. Each bundle contains much hair that is shorter than the apparent length, and these different lengths, as also colours, have to be separated and any dirt removed before the bristles are fit for the use of the brush maker; effected by passing the hairs through graduated combs formed of vertical metal points in wood blocks fixed to the workman's bench. The value depends upon the length, strength, colour and *solidity*, the last meaning uniformity of length of all the hair in the same bundle; pure white is the most valuable.

"Russian bristles are of two classes, the firsts or 'Petersburg,' sent in bundles of 5 to 7 inches diameter of about 3 lbs. weight, are strong and contain little of light colour. Siberian, the second class, are in smaller bundles of about half the weight of the first and contain a large proportion of white; these bristles are less taper and the flag is shorter, properties which add to their utility, but they are of less length than the firsts. Both classes are of varied qualities known as Okatka, first sort, Suchoy, second sort, and Riflings; the first named is the stiff hair from the spine, measuring from 5½ to 7 inches in length; Suchoys and seconds are softer and shorter;

Riflings are the refuse combed out in the first collection of the bundles, these are received entangled together and are of small value. The total quantity of bristles annually exported from St. Petersburg is about 20,000 cwt., of the estimated value of £300,000. The supply next in importance is collected in Galicia and the countries running south to the Black Sea, known as German or Polish bristles, the principal market being at Leipsic. Of late large quantities have been imported from India and China. Indian are dark and somewhat dirty in colour, the thickness rapidly diminishing at a short distance from the root and the flag long and *spiry*, which detracts from their value. China bristles have no great length or stiffness, on the other hand they are mostly of an exceedingly bright and shiny black, uniform, well selected and packed, usually two bundles in a neat paper packet which is marked with the length."

BRITANNIA METAL works, like those in hard pewter, which this alloy considerably resembles, after having been turned are in great measure finished by the steel burnisher with an abundance of oil; the final lustre is usually given with rottenstone and oil on woollen rag. Frequently a very minute coat of oil is left as a defence to retard the action of the atmosphere, at other times the surfaces are thoroughly brightened with dry whiting, applied on wash leather.

Many workmen polish Britannia metal with Trent sand and oil, to the exclusion of all other applications. This sand is probably unequalled as to fineness.

BRONZE.—The Bronze metal, (copper and tin,) is now usually called gun-metal, or bell metal, according to its proportions, and is polished after the manner of BRASS, which see articles 1 to 5.

The colours of bronzes, imitative of those tints which occur on the metal from long exposure to the atmosphere, are sometimes produced chemically in the modes described, Chapter XIII.

BRUSH WHEELS, circular revolving brushes made of bristles or of wire are used with various polishing materials, see WHEELS, article 68. Hand polishing brushes are also used, which are made almost like nail brushes, but many of them are longer, narrower, and also softer, especially such as are used by watchmakers, jewellers, and others.

BUFF LEATHER is used in various ways for polishing; thus it is glued on the circular edges or plane surfaces of wooden polishing wheels, and used with coarse emery, crocus, rottenstone, and other powders, see WHEELS, articles 53 to 62.

BUFF STICKS are parallel rods of deal upon which strips of buff leather are fixed, either by means of glue, or by folding the leather around the ends, and securing it by iron tacks. The buff sticks are principally used with crocus and rottenstone, both with or without oil, and for most of the metals as well as various other substances; in some few cases the buff stick is moistened with water, see TORTOISESHELL.

BUFF WHEELS are described under the head WHEELS, articles 53 to 56.

BURNISHER.—This valuable instrument is in general a piece of hardened steel very highly polished, and when judiciously applied to the smooth surfaces of metals, it imparts to them by means of friction, or intimate contact, a polish nearly equal to that which the burnisher itself possesses.

2.—THE ACTION OF THE BURNISHER appears to depend upon two circumstances; first, that the harder the material to be polished the greater lustre it will receive, and the burnisher is commonly made of *hardened steel*, which exceeds in hardness nearly every metallic body. And secondly, its action depends on the intimacy of the contact betwixt the burnisher and the work; and the pressure of the brightened burnisher being, in reality, from its rounded or elliptical section, exerted upon only one mathematical line or point of the work at a time, it acts with great pressure and in a manner distantly analogous to the steel die used in making coin; in which latter case, the dull but smooth blank, becomes instantly the bright and lustrous coin in virtue of the intimate contact produced in the coining press, between the entire surface of the blank and that of the highly polished die. The polished superficies of drawn metal tubes and wires are also illustrations of burnishing, as they result from the uniform compression of the surfaces of the metals effected by the polished holes of the hardened steel drawplates through which they have passed.

It by no means follows however that the burnisher will produce highly finished surfaces, unless they have been previously rendered smooth, and proper for the application of this instrument; as a rough surface having any file marks or scratches will exhibit the original defects, notwithstanding that they may be glossed over with the burnisher which follows every irregularity; and excessive pressure, which might be expected to correct the evil as in coining, only fills the work with furrows, or produces an irregular indented surface, which by workmen is said to be *full of utters*.

Therefore, the greater the degree of excellence that is required in burnished works, the more carefully should they be smoothed before the application of the burnisher, and this itself should be cleaned on a buff stick with crocus immediately before use; and it should in general be applied with the least degree of friction that will suffice. Cutlers mostly consider that burnishers for steel are best rubbed on a buff stick with the finest flour emery; for silver however they polish the burnisher with crocus as usual, most of the metals previously to their being burnished are rubbed with oil to lessen the risk of tearing or scratching them, but for gold and silver, the burnisher is commonly used dry, unless soap and water or skimmed milk are employed; and for brass furniture, water with or without a little vinegar, or else beer is preferred for lubricating the burnisher.

3.—THE MOST GENERAL FORMS OF BURNISHERS.—The burnisher used by mechanicians generally, resembles in form a file of elliptical section without teeth; it is made particularly hard and well polished. For engravers in line and mezzotint, the burnishers are sometimes crooked like the horn of a cow; for watchmakers and others, they are flat so as to apply to pivots, and other

burnishers for these artizans are nearly cylindrical for the interior surfaces of pivot holes, in which they are applied as in using a polygonal broach. For ironmongery a narrow piece of steel is inlaid in a cross handle of wood, that is used almost like a spoke-shave, and the pressure is increased by a leather strap or bridle attached on both sides of the burnisher, in the bend of which the workman places his foot, to give the pressure. The same form of burnisher is employed in Sheffield for the springs of pocket knives, but the strap is generally omitted.

The burnisher is sometimes also fitted up with a handle at one end and a hook and staple at the other, somewhat like the paring knife used by clog makers and others, see fig. 18, Vol. I., page 26. This kind, which is called the *clog burnisher*, is much used at Sheffield for the backs and squares of knife blades, which, after they have been made quite smooth, are moistened with the tongue and burnished with the clog burnisher, then the work and tool are wiped quite dry with a clean linen cloth, and a very gentle dry burnishing completes the work.

Fender makers and others have the burnisher at the bottom end of a pole suspended from the ceiling, or rather from a long and strong spring like that of the pole lathe, or a straight coach spring; this enables them to take a very long and equal stroke. The same contrivance, (which is also used in calendering cloth by hand,) is nearly copied, but with a piece of leather and emery, for laying a straight and dull grain on long works.

Burnishers made of flint, agate, and bloodstone are used by bookbinders and picture frame makers, also by silversmiths and jewellers, and other artizans, see Bloodstone.

4.—Chain Burnishers.—These are composed of numerous series of interlaced rings about one quarter of an inch diameter, made of hard, bright, round steel wire of about one sixteenth of an inch thick. The rings are connected together as a network in parallel lines both along and across, the links running in the one direction being double or all of two rings. Pieces of this network are attached to backs of stout buff leather about five inches square, by the marginal series of rings which are passed through holes in the edges of the leather and then "jumped" or pressed again together. Strips of buff leather, their edges brought together as a tube, are surrounded with the chain work with a portion of the leather at either end left as a handle; or strips of the steel network only, about twelve inches long by two wide, are attached by their ends to pieces of leather for handles. These when wrapped once around the work have the ends pulled alternately, and the flat square form used in the palm of the hand, as readily adapts itself to the form of the work to be brightened. The chain burnishers are very serviceable to keep bright work such as bits, stirrup irons, etc., clean and in condition.

5.—Bone Burnishers.—These are six to ten inches long made from sheep and other bones cut or split in halves lengthwise, with the hollow side filed smooth to a flat concave and the edges rounded where they meet the natural surface of the rounder side of the bone, a kind of thick paper knife, the section of a crossing file, fig. 806 M. Vol. II.; some are thinner and more like a paper

knife. They are used for burnishing many soft materials, and extensively by the Sheffield tool makers for finishing the edges of wooden braces, beech saw handles, and similar tools. The saw handles which are parallel throughout their substance are sawn out, rasped and filed to shape and smoothly finished with glass paper, applied to their surfaces on flat cork rubbers and to their rounded edges in the fingers, and on pieces of cork and wood. The bone burnisher held by both ends is then forcibly rubbed lengthwise and dry, all over the rounded edges of the saw handle from the tops of its curvatures downwards each way to the side surfaces, which are left untouched; the outer edges and those of the aperture for the hand in a hand-saw handle, are completely burnished in less than two minutes. The compression exerted either with or against the grain leaves the wood lustrous in contrast with the glass papered sides, and is a striking illustration of the action of the burnisher explained in article 2.

CALSH.—A natural and very friable earth found in small masses, composed of finely comminuted particles of carbonate of lime free of admixture; imported from Vienna in small broken pieces, nearly pure white in colour. A few pieces partially crushed and sprinkled with water, disintegrate after a few days into a fine powder of remarkably even quality, ready for use; sometimes the powder is passed through a muslin sieve. Employed for polishing Amber and Meerschaum, see Vol. IV., p. 570.

CANNEL COAL.—In polishing flat works of this material, such as inkstands, water of ayr stone in the stick is 1st used with water; 2ndly, charcoal dust and soft soap on a flannel; and although 3rdly, for fine works rottenstone on the hand or flannel have been used, it is better to continue the second process until the completion, adding only additional soft soap with water as a lubricator. For the working of cannel coal, see Vol. I., p. 162.

For objects turned in the lathe, the water of ayr stone is superseded by emery paper.

The Lapidary works Cannel Coal just as he would Alabaster; see Article 3 under that head.

CAOUTCHOUC.—*See* India Rubber.

CAP.—A term used by many of the Sheffield Cutlers to designate wooden wheels, *capped* or surrounded with a ring of metal to constitute laps, the edges only of which are used, see Wheels, articles 39 to 49, where their construction and application are described.

CARBON, when highly crystallized, as in the diamond, is the hardest substance in nature, and cuts all others. Next in hardness to the diamond are those mineral substances having for their bases alumina, silex, and the metallic oxides of iron and tin. See also the articles on Diamond and Charcoal.

CARBUNCLE.—The stone that is considered to have obtained this name in ancient as well as in modern times, is the Almandine, or Precious Garnet of minera-

logy; it is usually polished *en cabochon*, or with a rounded surface without facets, after the general manner of oriental jewellery, and is worked like CARNELIAN, as described in the following article.

CARNELIAN is the substance that has been selected as the example of the mode of cutting and polishing stones of a medium degree of hardness, the two other examples being Alabaster for the softest stones, and Sapphire for the hardest, excepting alone the diamond, which last is worked in a manner peculiar to itself, and is separately considered. As already observed, some of these subjects will be resumed more at length in Chapter X. on Lapidary work.

1.—CARNELIAN when operated upon by the Lapidary, is, 1st, slit with the thin iron slicer fed with diamond dust and moistened with brick oil; 2ndly, it is rough ground on the lead mill with coarse emery and water; and, 3rdly, it is smoothed either on the same lap rubbed down fine, or with a similar lap used with finer emery; thus far the steps are precisely as explained with regard to Alabaster.

4thly. Carnelian and stones of similar or superior hardness which are not smaller than about one third of an inch in diameter, are in almost all cases polished on a lead mill plentifully supplied with rottenstone and water; but this fine powder will scarcely adhere after the manner of the coarser and granular emery, or by simple pressure and therefore to expedite the process the face of the polishing lap is *hacked*, or *jarred*, although in a manner quite different from that pursued by the cutler.

The Lapidary employs the blade of an old table knife which he holds slenderly between the thumb and finger, placed near the middle of the blade, while the front part of the edge rests on the lap, not perpendicularly, but slanted a little forwards, so as to meet the lap edge foremost during its revolution: the unstable position of the knife causes it to jump, vibrate, or chatter on the lap, and at each jump it makes a very slight furrow; these fill the face of the mill with minute lines or grooves, that serve for the lodgment of the finely powdered rottenstone. It is however to be observed that the wheel should be made first to revolve in the one direction, and then in the opposite, that the marks of the hacking-knife may cross each other.

2.—Smaller and harder stones are more commonly polished on a pewter than a lead lap, and for the smallest and hardest stones a copper lap is preferred; but all the polishing tools, of what metal soever they may be made, are hacked as above described, and used with rottenstone and water.

3.—ROUNDED OR CONVEX STONES, or those said to be cut *en cabochon*, whether of Carnelian or even several of the harder stones, are in many cases successively wrought by means of the wood mill with fine emery, the list mill with pumice-stone, and leather lap with putty powder, precisely as described under the head Alabaster. This is done on account of the greater elasticity of these apparatus, which enables them to ply more conveniently to the globular forms of the works to be polished, and avoid wearing them in ridges or flat places.

4.—FACETTED WORKS on all stones and hard substances, are for the most part cut by the Lapidary after one of three different modes. First, for pastes or arti-

ficial stones, and many soft stones, as amber, carnelian, jet, &c., the facets are usually cut on a lead wheel with emery, and polished on pewter with rottenstone.—Secondly, for some of a harder kind but inferior in hardness to sapphires, the succession of tools is a pewter lap and fine emery for the cutting, and a copper lap with rottenstone for the polishing.—Thirdly, for sapphires, the chrysoberyl, and rarely for some few others likewise, a copper lap with diamond powder is used for cutting the facets, and a copper lap with rottenstone for polishing them.—And fourthly, with the diamond, two stones are rubbed in a peculiar manner the one against the other to cut the facets, and they are polished by means of the *dop*, and an *iron* lap or *skive* fed with diamond powder; this process is more fully described in Vol. I., page 176.

5.—From the comparatively small size of the stones and gems that are cut into facets, they cannot generally be held unassistedly in the fingers, the stone is consequently cemented centrally upon the end of a round stick of wood, nearly like a drawing pencil. The stick when held *vertically*, gives the position for grinding the central facet or *table* of the stone, the stick is inclined to a certain angle for the eight, twelve, or more facets, contiguous to the table; of which facets, two, three, or four series are commonly required at different inclinations, and, lastly, the *horizontal* position of the stick serves in cutting the girdle or central band around the exterior edge of the stones.

The several inclinations of the stick on which the stone is cemented, are easily determined by placing its upper end into one of several holes in a vertical post, fixed alongside the lap, and this retains the inclination very accurately and simply, but these and other matters will be further elucidated in the chapter on Lapidary Work generally.

6.—The following substances are worked by the lapidary in nearly or exactly the same manner as carnelian, and descriptive articles are introduced in the catalogue upon each of these particular substances, pointing out their principal external features, and also any peculiarities of method, pursued either by the lapidary or other artizan, as the case may be, in working them.

(SUBSTANCES TREATED BY THE LAPIDARY LIKE CARNELIAN.)

Agate	Elvans	Mina Nova
Amethyst	Emerald	Onyx
Aquamarine	Felspar	Opal
Beryl	Flint	Pastes
Bloodstone	Fluor Spar	Peridot
Brazilian Topaz	Garnet	Plasma
Carbuncle	Granite	Porphyry
Cat's-eye	Heliotrope	Quartz
Chalcedony	Jade	Rhodonite
Chrysolite	Jasper	Sard
Chrysoprase	Labrador	Sardonyx
Crocidolite	Lapis Lazuli	Serpentine
Crystal	Marble	Topazes.

CAST-IRON.—When the parts of machinery that are made in cast-iron are polished they are treated as described in this catalogue under the general article on MACHINERY made of iron and steel.

THE FRONTS OF STOVES, and similar bright works in cast-iron, are first ground on large grindstones, and then buffed on large revolving buffs upon which a coating of emery has been fixed by glue. They are sometimes finished by a hand rubber used as a spokeshave having a piece of leather supplied with fine emery and oil, but the rubbers suspended from the ceiling at the end of a powerful spring, are also very judiciously employed in these large works. See BURNISHER, article 3.

FIRE IRONS are often cast in iron that is afterwards rendered malleable; which is a rapid way of producing beautiful form, combined with strength and a certain measure of flexibility, see Vol. I., page 259, the works are afterwards case-hardened, that they may admit of a better lustre, which is generally given by grindstones, glazers, buffs and brushwheels, much the same as in cutlery but on a larger scale.

CAT'S-EYE, a mineral consisting of quartz enclosing amianthus or asbestos, and thence possessing the property emphatically described by the French as *chatoyant*; good specimens of this beautiful stone are of high value for jewellery, and this has led to the employment of Crocidolite, which see, and of fictitious cat's-eye for yet inferior ornaments; the true cat's-eye is polished just like AGATE or CARNELIAN.

CELLULOID.—*See* XYLONITE.

CHALCEDONY, a name applied to many siliceous minerals including as varieties the onyx, sard, sardonyx, plasma, heliotrope, and chrysoprase: they are wrought like CARNELIAN, which see.

CHALK when simply scraped, or else crushed under the hammer, is occasionally used in polishing bone, ivory, and some few soft substances, it cuts much more quickly in its natural state as above, than when manufactured into the well known article Whiting. When used for polishing well finished works in ivory the practice of washing the finely crushed chalk to remove its gritty impurities, in the manner described for EMERY, article 2, is essential. The ordinary whiting of commerce, more frequently used for best works in ivory, usually contains some grit, and should also be washed.

2.—WHITING is made by grinding the chalk under a runner, washing it for the removal of sand and other impurities, and then drying it in lumps. In the prepared state the particles of the chalk are so smooth, as hardly to abrade any but very soft materials, such as ivory, therefore, the principal use of whiting when applied to the metals seems to be the absorption of the grease from works previously polished by other means.

3.—CHALK PREPARED BY DOUBLE DECOMPOSITION.—A mode of preparing this polishing material so as to obtain it perfectly free from silex, (which sometimes accompanies the ordinary kind and is a very active polishing material,) is as

follows. Mix filtered and transparent solutions of the *muriate of lime*, and the *carbonate of soda*, when these are thrown in contact, the muriatic acid quits the lime and combines with the soda, making common table salt, and the carbonic acid and lime unite and fall down as an impalpable precipitate, which may be collected by filtration. The pure carbonate of lime thus prepared polishes quickly and smoothly, and nevertheless wears away the material so little as not in any perceptible degree to injure its form or sharpness, it seems rather to burnish than abrade the work.

CHARCOAL.—Sticks of this material are very extensively used for polishing several of the metals, and the action seems to depend on the silex disseminated throughout its substance. Considerable discrimination is required in the selection of pieces from the bulk of that which is prepared from small green wood for metallurgical and domestic purposes, as but few pieces possess the requisite cutting quality; the workmen generally try it either on the teeth or finger nail.

The stick of charcoal is applied at an angle of about 40 or 50 degrees to the work, the position best suited to every piece being found by trial. Some pieces will cut rapidly and coarsely with water, others more slowly and smoothly with oil; pieces of good quality are very highly prized by workmen. Some artizans conceive that charcoal cuts more greedily when moistened with vinegar, but this fluid is objectionable as it stains the metals. In the course of polishing, the charcoal picks up the abraded particles of metal, they sometimes enter its pores and would scratch the work if allowed to remain; consequently two pieces are mostly used, the one merely to clean the other by rubbing them together at their ends in the same manner that the painter rubs two lumps of pumice-stone together to clean their surfaces. In finishing delicate works, and laying the grain, abundance of oil or water should be used so as to float off the minute particles of metal removed in the process.

The charcoal prepared from the wood of elder appears to have the decided preference especially for polishing the steel and copper plates used by engravers, both in their first preparation and in the removal of the burrs thrown up by the graver. To ensure the possession of the true sort, it is recommended to obtain the waste pieces of elder from the rule maker, to cut them into short pieces, and then to burn them in a crucible filled with sand, in order to exclude the air, otherwise the entire substance of the wood may be burned to ashes; the kitchen or forge fire may be used, and the crucible should be allowed to cool in the embers. The charcoal made from willow truncheons is said to be much in esteem by the manufacturers of copper plates for engravers.

CHARNLEY FOREST STONE.—*See* HONE SLATES, article 2.

CHRYSOBERYL, a hard aluminous stone, of a green colour, and semi-transparent; it is chiefly procured in Brazil, and is worked like the SAPPHIRE.

CHRYSOLITE or PERIDOT, a yellow gem, sometimes tinged with green or brown, occasionally as green as but duller than the emerald; obtained princi-

pally from the Levant. It possesses a peculiarity, inasmuch as although it is slit and facetted just like Carnelian, it can scarcely be well polished, otherwise than by means of a copper lap with rottenstone, a few drops of *sulphuric acid* being used instead of water to moisten the rottenstone.

CHRYSOPRASE, a variety of CHALCEDONY, of an apple green colour, semi-opaque, rare and much prized by jewellers. It is peculiar in gemmology as the only precious stone which contains nickel, to the presence of which metal it owes its technically termed and beautiful *sleepy green* colour. It is cut and polished after the mode of Carnelian, and frequently of a convex form, or *en cabochon*.

CLAY.—*See* LOAM.

CLOTH is extensively used as a vehicle for polishing powders of all kinds; woollen and felted cloths are the most in requisition. Some of the felted cloths used for marble, glass, &c., which are called *nap*, are upwards of half an inch thick. Thinner cloths, such as the stout cloths used for great coats and for the blankets of printing presses, are also employed, especially when discarded from their original purposes, and also ordinary woollen cloth, including the list, or selvedges, and so on.

Old worsted stockings are used in many trades; linen and cotton cloths and rags are also employed, but, from being thinner, are less generally used than woollen cloths.

CLOTH WHEELS, *see* Wheels, articles 63 to 67.

COLCOTHAR OF VITRIOL.—*See* OXIDE OF IRON.

CONES.—The principal modes of grinding cones will be explained in Chap. VII., sect. 3.

COPPERSMITH'S WORK, subsequently to its having been annealed for the last time, and before it is planished with the hammer, is generally pickled with sulphuric acid and water, in about equal parts, and scoured with coarse red tripoli and water, to remove the oxidation caused by the fire. The work when planished is cleaned, 1st, with crocus and oil, 2ndly, the oil is rubbed off with whiting, and 3rdly, the work is polished with dry crocus, the rubber being generally an old worsted stocking.

COQUILLA NUT receives a good natural polish by the following applications:—1st, glass paper; 2ndly, tripoli and oil on rag; 3rdly, dry putty powder or rottenstone. This routine gives a more durable polish than hardwood lacker applied with friction, a mode of finish also employed.

Common turned and filed works are often finished with one or two coats of varnish, applied like paint with a brush, this gives them a coarse brightness.

Eccentric turned works in coquilla nut are polished very slightly with putty powder or rottenstone and oil on a brush; but the tools should be very sharp, so as to leave but little or no necessity for polishing at all.

CORAL.—The red, pink, and white varieties of this singular substance are used in jewellery, and admit of an excellent polish. When in rounded pieces, it is polished after the routine followed by the lapidary with ALABASTER; when coral is cut in facets as for beads, &c., it is worked like CARNELIAN.

CORK.—The bark of the Quercus Suber, a variety of the oak, native to the south of Europe; a list of the uses of this valuable material would be almost endless.

1.—In handicrafts cork is extensively used for rubbers with which to apply abrasive materials; glass-paper is wrapped around flat rectangular pieces a few inches long and wide by the cabinet maker and others for finishing the surfaces of flat works, and upon pieces with rounded edges for smoothing mouldings; it is also used as rubbers impregnated with the polishing materials on tortoise-shell, mother of pearl, &c. Small works in metal indent the surface of, and are thus held, by pieces of cork with which they are moved about in straight and circular strokes by the hand, upon the stone or metal surfaces fed with the powders and oil upon which they are ground and polished flat. Similar works are often laid upon cork covered pieces of wood held in the vice, and retain their position by indenting the yielding material whilst being filed, &c.; and slips of cork are placed between the jaws of the vice, or glued within the jaws of wooden vice clamps, to grip works without injury to already finished surfaces.

2.—Among less apparent use, ground to a fine powder, cork is one ingredient in some polishing or glazing emery wheels, and is added to clog or retard the action of the already fine emery powder in these polishers. Pulverized cork forms a large proportion of the material in the floor cloths known as Corticene and Linoleum. The French material Liégine consists of finely powdered cork, with a less proportion of plaster of Paris, size, and a little colouring matter; this is pressed into moulds to replace plaster, carton pierre, &c., for cornices and other interior decoration, than which it is lighter and more durable; it is used in sheets as a non-conductor of damp, heat or sound.

COROSOS or the vegetable ivory nut, *see* Vol. I., page 112, is polished just the same as the ivory of the elephant and other animals; but the vegetable ivory, apparently from its facility of absorbing moisture, alters sensibly in size and form during the process of polishing.

CORUNDUM includes very dissimilar minerals, all consisting almost entirely of highly crystalline alumina, namely,—Precious Corundum, or the Sapphire and Ruby,—Common Corundum—and Emery.—The last two are the common abrasives of the Asiatics and Europeans respectively; and all are separately described under their respective heads in this catalogue.

1.—COMMON CORUNDUM, says Phillips, probably from its texture, has received the name of *imperfect* Corundum; and from its hardness, and from its occasional pearly lustre, *Adamantine Spar:* it occurs everywhere from China to Bengal, and is met with of various colours, but more often of a greyish or greenish tint. Corundum is much used in India for Corundum Wheels and Rubbers, the methods of constructing which are described in articles 2 and 4, now fol-

lowing. Grinding wheels, some of large size, made of American Corundum, are also commonly in use, these are similar in form and construction to Emery wheels, for which see Emery, article 12 and later pages.

2.—Corundum Wheel.—"This kind of lapidaries' wheel is called in the *Tamul* language *Couroundum-sane.* It is composed of *corundum*, more or less finely powdered, cemented together by lac-resin: the proportions, by volume, consisting of two-thirds of powdered corundum and one-third of lac-resin. The corundum powder is put into an earthen vessel and heated over a clear fire; and when of a sufficient heat, (which is ascertained by a small piece of the resin readily fusing,) the resin is added in portions, carefully stirring at the time, to form an intimate mixture. When made into a mass, it is put upon a smooth slab of stone and kneaded by beating it with a pestle; it is then rolled upon a stick, reheated several times, continually kneading it until the mixture is perfectly uniform. It is afterwards separated from the stick, laid again upon a stone table which has been previously covered with very fine corundum powder, and flattened into the form of a wheel by an iron rolling pin. The wheel is then polished by a plate of iron and corundum powder; and finally, a hole is made through the middle of it by a heated rod of copper or iron. "These wheels are made with a grain more or less fine, as the coarser perform the first rough work, and the finer cut the stones. They are mounted on a horizontal axis, and the workman, sitting on the ground, as illustrated, Vol. IV., figs. 5 to 9, makes them revolve with a spring-bow, which he moves with his right hand, at the same time holding the stone with his left against the wheel, the latter being, from time to time, carefully moistened and sprinkled with corundum powder. The polish is given by wheels of lead and very fine corundum powder."

3.—Small Corundum Wheels, of fine grain, made both here and in America, and compounded with shell lac, but also with silicate of soda, ranging from half an inch to about three inches diameter and from less than one-sixteenth to about half an inch in thickness, with knife-edge, rounded, square and angular edges, are used by mechanical dentists, mounted in their small grinding lathes driven by the foot.

These little grinding wheels mounted in the apparatus, Fig. 74, or upon spindles to run between centers in the lathe, lubricated with oil and driven at speed, are valuable for renovating the concave cutting edges of the bead drills, tools and cutters used for ornamental turning and illustrated in Volume V.

4.—Corundum Rubbers.—"The proportions generally used in making the corundum rubbers are, for the coarse, lac, 8, corundum, 1; for the medium, lac, 12 to 16, and corundum 1, by weight. The fine rubber is made by mixing the grindings of agates, carnelians and the like, with lac; and as the lapidary's wheels, upon which they are ground, are made of corundum and of lac also, the grindings must contain a portion of those materials; their proportion, in composition, must vary according to the nature of the stone from which they are ground; but 6 of lac to 1 of grindings, may be considered a good proportion generally.

"The lac is first melted, and the corundum, after it has been reduced to a powder, mixed intimately with it. The composition is then moulded in the shape of a brick about 6 × 4 × 1½ inch, with a handle of wood about 6 inches at one end, having a rise of about 30 degrees for the convenience of working it."

Some dentists employ old files thinly coated with a cement of emery and shell lac, in finishing the enamel or mineral teeth. The incorporation of the materials is greatly assisted when the emery or corundum is heated to the melting point of the gum resin.

CROCIDOLITE, or TIGER EYE, a fibrous asbestiferous mineral composed of silicate of iron, magnesia and soda, found in the Griqua country, South Africa; colours dark rich brown and yellow, also and rarer, lavender-blue and leek green, varieties containing salts of copper. Turned about in the light at different angles it displays strongly developed and splendid changes of colour, shown in broad iridescent bands and wavy streaks of brilliant gold and browns shading into one another, with a few transverse markings. It is used in common jewellery to imitate CAT'S EYE, and large pieces, not uncommon, are made into spheres and other shapes for stick and seal handles, etc.; usually cut *en cabochon* and worked after the manner of carnelian.

CROCUS.—*See* OXIDE OF IRON.

CRYSTAL, or ROCK CRYSTAL, is a popular name for Quartz, or pure crystalline silex, the finest and largest crystals of which are found in Madagascar, Dauphiné, and the Alps; the so called Bristol diamonds are nothing but fine specimens of quartz cut and polished.

The Brazilian pebbles for spectacles are lenses ground out of pure, transparent, colourless quartz. The stone is cut into slices by the lapidary, afterwards it is snipped into the form of the lenses with nippers which resemble wide flat pliers, and are made of soft iron in order that the quartz or glass may slightly imbed itself, to gain a hold, which could not take place with the hard steel faces of ordinary pliers; lastly the pieces of crystal are ground into the form of lenses and polished by the optician, exactly in the same mode that he employs for glass lenses, which will be described.

Numerous specimens of antique cups, tazze and other works of art, formed entirely by abrasion from rock crystal, or quartz, are to be found in every National Museum, and are even more remarkable for the laborious perseverance given to their production than for the beauty of the material and, usually of their forms.

CUTLER'S GREEN HONE.—*See* HONE SLATES, article 6.

CUTLERY is ground and polished with the various natural and artificial grinders, the constructions and applications of which are described under the article WHEELS in this Catalogue: the ordinary succession of the principal processes will be therefore alone adverted to in this place.

1.—Fine Cutlery.—The manufacture of a razor blade of the best quality may be viewed as a suitable example of the mode of treating articles of fine cutlery: the succession of processes is as follows:—1st, the blade is moulded; 2ndly, forged; 3rdly, ground into form and *scorched*, or the black scale ground off: this is done on a dry coarse Wickersley grit stone; 4thly, the blade is drilled for the joint and stamped with the name; 5thly, hardened and tempered, see Vol. I., page 248; 6thly, ground on a wet Wickersley grit stone from 4 to 8 inches diameter; 7thly, the shoulders of the blade are sometimes ground on a fine dry stone; for this purpose the edge of the stone is *waxed up*, or kept keen by rubbing bees-wax on the side near the periphery to hold the particles of the stone together; the wax keeps the stone from crumbling away, but the dry stone should be sparingly used after hardening as it is liable to soften the edge of the blade; 8thly, the blade is lapped on a lead lap of a diameter a little smaller than the grindstone employed in the 6th process—the lap scarcely alters in course of use and gives the true curve to the surfaces; 9thly, the tang and back are glazed on a leather glazer; 10thly, the razor blade is polished on a soft buff wheel fed with dry crocus and revolving very slowly. This completes the manufacture of the blade, which is then ready to be handled preparatory to the setting, which will be described in Chapter II.

The best penknife blades and scissors are treated in a similar manner to the above.

2.—Common Cutlery.—All work should be scorched or dry ground to remove the scale before hardening, but this is frequently omitted in common works, and the usual routine after hardening is, 1st, the coarse wet stone; 2ndly, the fine wet stone; and, 3rdly, the buff with fine emery. Sometimes one or more intermediate stages between the extremes for the common and best cutlery are resorted to, according to price. Common razors, after being hardened, are, 1st, ground on a wet stone from 12 to 15 inches diameter 2ndly, lapped; and 3rdly, polished.

3.—Edge Tools are treated the same as common cutlery.

DEVONSHIRE OILSTONE.—*See* Hone Slates.

DIAMOND, this remarkable and most useful gem has been considered at some length in the first volume, pages 175–180—first as regards the processes of splitting, cutting, and polishing diamonds for jewellery,—then its use in the hands of the glass-cutter and glazier—and lastly several of the uses of the diamond as tools, which applications include the formation of the jewelled holes of ruby and sapphire for watches and chronometers, every process of which requires the intervention of the diamond. Splinters and fragments split off the gem in its preparation for cutting and polishing into facets, page 176, Vol. I., known as *diamond bort*, are used for the above mentioned small boring and turning tools, and the gem is rarely employed in its natural state except for the diamonds used by glaziers, in which case it is always small stones that from flaws or bad colour are useless as gems, such stones are also classed as bort; on the other hand two curious varieties of the diamond,

the Brazilian Ballas or Ball bort, and Carbonado or the Carbonate diamond, are employed in their natural condition as abrasive or quasi-cutting tools.

Ballas or Ball Bort occurs in small nearly spherical nodules, semi-translucent, and possesses a radiated internal structure, hence the collected crystals have a radial instead of the octohedral fracture of the diamond or gem; ballas is uncommon. It is mounted in stems in the manner described in a later page and in the notice of the use of this tool, page 348, Vol. IV., it has no cutting action but abrades the material by the hard and rather rough exterior rind formed by the ends of the collected crystals.

Carbonado or Carbonate Diamond, a still more peculiar variety, was discovered in the diamond gravels of Brazil in 1842, and has since been found in Siberia. Carbonate bears no resemblance to the diamond; it occurs in small irregularly shaped pieces with rough surfaces which frequently contain minute cavities, it is dark brown to nearly black in colour, opaque and absolutely non-crystalline with an amorphous fracture; viewed with a magnifier it has the appearance of a piece of coke, hence, probably, its Spanish name carbonado. It is the hardest and toughest of all the diamonds; the original pieces or these reduced in size by fracture are mounted in the stems and used as described in later pages; for some exceptional purposes the carbonate fragment is partially shaped by grinding, which can be executed only upon another piece of the same material.

In this place it is proposed to describe the three different modes in which the diamond powder is prepared for the use of various artizans, its applications by the lapidary, gem engraver, and others being left for future chapters, and then to briefly notice the prototypes and the applications of the gem and carbonate diamonds as actual tools, the practice with which will, in like manner, be found in later pages.

2.—Diamond Powder for Lapidaries' Use.—Lapidaries generally purchase small imperfect diamonds, and the fragments removed by splitting or cleavage in preparing stones for jewellery. These fragments are crushed in a hardened steel mortar, fig. 313, with a cylindrical hole about half an inch diameter and nearly two inches deep, the bottom of the cavity is hemispherical or constitutes perhaps the third part only of the circle, the pestle almost fits the aperture of the mortar, and is curved to the same degree, there is also a cover that fits a recess in the mortar to prevent the escape of any of the valuable dust.

The pestle is struck a few blows with a light hammer, and is twisted round between each blow, this readily crushes the diamond, which, although so incomparably hard, is brittle from its crystalline structure. The fragments are carefully collected, and mixed with a little of the oil of brick in a small cup or any convenient vessel, which should have a cover to keep the prepared diamond from being wasted. When not wanted for immediate use, the prepared diamond is kept in a pasty condition between two very small watch glasses, cemented with soft wax around their edges.

3.—Diamond Powder for Seal Engravers.—This is required to be much more finely pulverized than for lapidary work, therefore having been crushed as above, the fragments are ground into a thick paste with a few drops of

olive oil, in another pestle and mortar of hardened steel, the surfaces of which are both exactly spherical with a curvature of from one to two inches radius; this mortar has a tin cover that it may serve as the recipient for the powder which has been ground. Sometimes for reducing the powder after it has been crushed, flat grinders of hardened steel are employed, but these are less generally used than the spherical form. Rough diamonds of a dark steely colour are generally selected by the seal engravers, as these are considered the hardest stones.

4.—Diamond Powder for Watch Jewellers.—These artizans who use much larger quantities of diamond powder than the above, for cutting as well as for polishing rubies, sapphires, and topazes, pursue a different method. They purchase the fine dust, or *diamond bort*, that is rubbed off stones used for jewellery in the act of cutting them into facets, in which process two diamonds are operated upon at once, and caused mutually to abrade each other in forming the one facet on each stone; see Vol. I., page 176. The diamond bort is usually washed for its separation into two or three sizes, exactly after the manner of washing emery, except that the process is carried on upon a very much smaller scale, and the finest olive oil is used instead of water, the diamond powder is generally laid by under a stratum of oil to prevent waste; oil is employed because of its viscidity, it does not allow the diamond to subside so quickly as water, and it is moreover the fluid always employed in the using and preservation of the diamond by these artizans.

5.—The Application of Diamond Powder to the splitting or sawing of minerals will be described in the chapter X. on Lapidary work. The coarser diamond powder used for grinding or cutting is generally burnished into the surface of the iron lap or *skive* of the diamond worker, and frequently also into the iron, copper, or other laps used by different artizans: in cutting sapphires the lapidary works the diamond powder into the copper lap, with a smooth piece of agate applied with gentle pressure. The finer diamond powder used for polishing, is simply applied on the surface of the tools, with the finger, or a small flattened wire used as a spatula. The gem engraver puts the diamond in minute hollowed discs of tin, two of which in fact are soldered to a strip of tin, and worn on the forefinger of the left hand as a ring: the one disc, of half an inch diameter, contains the mixed diamond paste, the other disc, one or two drops of the oil of brick, with which the tool is frequently lubricated.

6.—Diamond Drills, fragments and splinters of the gem mounted in the ends of wires as described p. 178, Vol. I., are used for boring the diamond, ruby, and sapphire holes for horological work and for hardened steel; also for the preparation of the minute holes of accurate diameters in the diamond and sapphire discs used in a particular variety of drawplates, for which see Sapphire, article 3. Larger pieces of diamond bort, mounted after the same fashion, are employed for boring or enlarging holes, previously pierced, up to about one-tenth of an inch diameter; larger holes to about one-quarter of an inch diameter are preferably bored with the carbonate variety, the fragment mounted as shown fig. 386; for still larger holes up to about

one-inch diameter in stone, granite, and porphyry, two or more pieces of carbonate are mounted in the ends of steel stems, fig. 389; and from this size up to about 24 inches diameter, numerous pieces of carbonate are variously mounted around the annular faces of steel tubes for rock and other deep boring as described in Chapter XII.

7.—DIAMOND TOOLS include writing diamonds, delicate fragments of the gem mounted in the ends of penholder-like stems; similar pieces which are also often ground to delicate conical points, and for cutting lines of graduations in dividing engines and for tracing delicate lines and patterns on glass and metal in the ornamental turning lathe, and in pentagraph machines for engraving and other purposes; the diamonds for cutting sheet and plate glass; and pieces of diamond bort and of carbonate for dressing millstones; all of which may be classed as scoring or planing tools. The TURNING TOOLS comprise morsels of bort mounted in the ends of wires for turning diamonds and other gems and hardened steel; larger pieces fixed in stems, figs. 390 to 392, for the slide-rest and as hand tools, and fragments of the carbonate mounted in the same manner used for turning hardened steel, emery wheels and grindstones, marble, granite, and porphyry, particulars and the manipulation of all which tools are given in later pages.

8.—DIAMOND TOOTHED SAWS.—Straight, thin, and circular saw-blades, armed along their edges or peripheries with very small pieces of diamond bort or of carbonate, are employed for sawing marble and other hard stones; and other long reciprocating saws of small triangular section, with larger pieces inserted all along one edge, are now used for curvilinear stone sawing; their applications are fully described in subsequent pages.

9.—There is little doubt that all even to the latest applications of the diamond as a tool are revivals, although frequently amplifications, of its similar use in remote ages. The following particulars taken from a paper contributed by Professor W. M. Flinders Petrie to the Journal of the Anthropological Society, 1883, refer to the date 2400 B.C., and are of the highest interest, beside the identification of long lost processes. To solve the problem suggested by Brugsch in his History of Egypt, respecting the great diorite statue of Khafra, that,—"no master of modern times is capable of giving an answer to the question how they managed to overcome the difficulties of the unyielding substance"—Professor Petrie, in the course of his investigations in Egyptian archæology, collected an extensive series of fragments of basalt, diorite, granite, limestone, alabaster, &c., from the *débris* lying about the Pyramids, the rock-hewn tombs of Gizeh and elsewhere; which comprised examples of flat surfaces showing marks of the saw and sawn grooves, others pierced or partially pierced with round holes, some, highly suggestive, with more than one hole parallel with and cutting into one another, and also many cylindrical and tapering cores cut from out such holes: and this collection was then followed by careful investigation of similar workings *in situ*. Professor Petrie writes: "The principal result of the examination of these remains is the discovery that the stone cutting was performed by graving points far harder than the material to be cut; and that, as the stones operated

upon were quartz, or mixtures containing quartz, the graving points must have been, therefore, of some jewel harder than quartz; since no metal, not even the hardest tempered steel or osmiridium, is capable of cutting quartz, apart from a mere bruising action. These cutting points are found to have been embedded in a basis of bronze, in order to hold them in the right position and to move them with the required force." Professor Petrie considers it proved that the diamonds or other hard gems were mounted on the edges of saw-blades, and that the holes and solid cores prove the use of numerous sized tube drills and, almost as certainly, that of the diamond itself; this last point has not as yet been positively determined, but both cores and holes all show the irregular spiral markings and other characteristics which result from the use of the modern diamond tube drill. Different varieties of drills frequently occur in the sculptured records of Egyptian trades and occupations, and that the drills under consideration were made of bronze is the more probable from the circumstance, among others, that the cutting in the specimens of the lighter coloured stones is generally more or less stained green. Professor Petrie says,—"Although sawing was thus freely used for cutting the outsides of the great granite and basalt coffins, some other means were requisite for hollowing the insides of such vessels. Here the inventive genius of the fourth dynasty exactly anticipated modern devices, by adopting tubular drills as the readiest and cleanest way of removing material with the least waste of force. These tubular drills varied much in diameter, thickness and length. The smallest is one used in alabaster, only ·24 inch diameter and ·02 inch thick.* Other examples of small cores in alabaster vary up to ·52 inch diameter; a beautiful example of a mortar, the hollowing of which had been begun with a tube drill and which had been broken and thrown away, shows a drill ·7 inch outside diameter and about ·04 wide. A hole in a basalt vessel is 1·8 inch diameter, and a core in limestone shows a hole 1·9 inch diameter. A tubular drill hole in a lintel of the granite temple of Khafra, at Gizeh, is 2·2 inches diameter, and the thickness of the drill ·1 inch at the end: this is a particularly brilliant illustration of the form of the drill, as the core being in a tough patch of hornblende in the syenite would not break out, and hence a stump ·8 inch long still remains in the hole. This is the S. pivot hole of the doorway leading to the chamber with niches. A fine granite core on which continuous grooves can be traced is 2·2 inches diameter; it was found at Gizeh and is probably of the fourth dynasty. Alabaster cores from Gizeh are 2·5 and 2·8 inches diameter, and one of them shows the interference of the side of another drill-hole cutting into it. The drills used in hollowing out the granite coffer in the Great Pyramid were 4·2 inches in diameter, as we find by two places in which the drill was allowed to run too deep into the side; and as the bottoms of the holes are 7·7 and 8·4 inches below the top of the block, this probably

* It is more probable that this very small drill was a tube of the character of fig. 71, Vol. I., its annular surface fed with sand or other abrasive powder. The lapidary uses similar drills up to about ·50 diameter, fed with diamond powder for removing cores from the harder stones.

shows the length of the drill used to have been about two diameters."—"Two holes conjoined, in limestone, are 4·8 inches diameter, and show how closely holes were placed together for hollowing out masses; these drill-holes must have just overlapped by about the thickness of the drill, so that the greatest economy of labour was attained by using as much of the previous cut as possible, without scooping out any of the core of the previous hole."

The results of tubular drilling are also visible and upon a far larger scale at El Bershch, at which place the rock has been extensively cut away to make a platform in front of some tombs of the twelfth dynasty. The whole of this platform is covered with the circular grooves left by tubular drills of the astonishing size of 12 inches diameter; where it was not necessary to remove a piece of the rock the full size of a drill hole, the grooves intersect, and the cores and pieces between the borings have all been chipped or broken off, leaving a roughened flat surface. Hence, it is added in the admirable paper from which these extracts are taken,—"it seems almost certain that the tubular drill principle of which the previously mentioned examples range from about half to about five inches diameter was actually employed for removing masses of rock upon a large scale."

It is also very interesting to record that the modern invention and use of the diamond crown drill, by M. J. R. Leschot, a French engineer, of Paris, 1862, arose solely from the acute examination and speculations of that gentleman and his relative M. Georges Leschot, upon the parallel and regular spiral-like markings they observed on an antique porphyry core brought from Egypt, which it was clear to them had not been produced by any cutting tool.

With respect to the present supply of diamonds, Mr. W. J. Lewis Abbott, F.G.S., a high authority, in a lecture delivered at the British Horological Institute in November, 1890, gave the following particulars as regards one source alone. He says,—"Since the discovery of diamonds in South Africa, a period of about twenty years, 50,000,000 carats have been exported *legitimately;* and further, if we take the figures of the Postmaster-General, that in a period of three years, over a ton of diamonds passed through the Post Office, we can form some idea of the vast quantity which comes to this country."

10.—Fictitious Diamonds.—The white sapphire is sometimes used in jewellery as a substitute for the diamond, and the zircon is said also to be so employed when deprived of its colour by heat: the so-called Bristol diamonds are crystals of quartz cut and polished, but those imitations which are considered to come the nearest to real diamonds in point of lustre or colour, though not in hardness, are met with amongst the pastes of the first quality, which are made artificially, and polished on pewter wheels with rottenstone, and not on copper wheels, like most of the hard gems.

DUTCH RUSH, or the *Equisetum Hyemale*, is said to be a native of Scotland, and to thrive best in the marshy places in mountainous districts; it is gathered in pieces two or three feet long, which are intersected by knots at distances of

four to six inches. The rush is usually of the size of a writing quill, of a greenish-grey colour, with a groovy surface that feels rough like fine glass paper, from the quantity of silex disseminated throughout its exterior surface, and upon which circumstance depends its suitability to polishing hard woods, ivory, alabaster, marbles, and some other substances. According to the analysis of Sprengel, Dutch Rush, when dry, contains rather more than 13 per cent. of ashes, viz. Silex, 6·38, Carb. Lime, 5·51, Potash salts, ·79, and Alumina, ·46. For the application of Dutch Rush, see WOOD, article 5, ALABASTER, article 1, and Vol. IV., p. 471.

EDGE TOOLS are treated of under the head CUTLERY.

ELECTRUM or GERMAN SILVER.—*See* Silver, Albata, and Brass. The respective modes being used, according to the nature of the works made in this triple alloy, which differs greatly as to value and quality.

ELVANS, the modes of working and polishing porphyry and granite, and also the elvans, which are of intermediate character between these two, are described in pages 169 to 172 of the first volume, and in Chapter V. of the present volume. By the lapidary, the elvans and porphyries are wrought like CARNELIAN, the granite somewhat differently, on account of its unequal hardness, *see* GRANITE.

EMERY.

1.—ORDINARY PREPARATION OF EMERY.—The following is the manufacturer's ordinary process; the lumps of emery stone are broken up precisely after the manner of stone for repairing Macadamized roads, and into lumps of similar size. These are then crushed under stampers such as are used for pounding metallic ores, driven by water or steam power; the stampers are considered to leave the particles more angular than they would be if ground under runners, a mode sometimes employed, or the rough lumps are crushed in a stone-breaking machine, a pair of strong chilled iron, flat shaped jaws with corrugated faces, enclosed in a massive cast-iron frame open above and below. One jaw is fixed and vertical and the other, jointed on a hinge below, stands at an angle to it and is forced towards it by a link and eccentric driven by power. The joint of the reciprocating jaw is adjustable to or from its fellow, and the material fed in from above is crushed, and escapes through the narrow space left between their lower edges; thence the emery falls into the upper end of a long sheet iron cylinder, which revolves in a sloping position and has numerous perforations placed in four or five wide bands, each such series of holes of increasing dimensions, that the emery in dropping through may receive a first rough separation for size. The coarse powder is then sifted through sieves of wire cloth, which are generally cylindrical, like the bolting cylinders of corn mills, but the sieves are covered with wire cloth, having in general about 90 to 16 wires to the inch. The following table shows the numbers of wires usually contained in the sieves, and the names of the kinds respectively produced by them :—

16. Corn emery.	60. Coarse flour emery
24. Coarse grinding ——	70. Flour ——
36. Grinding ——	80. Fine flour ——
46. Fine grinding ——	90. Superfine flour ——
53. Super grinding ——	

No. 16 sieve gives emery of about the size of mustard seed, and coarser fragments extending nearly to the size of peppercorns are also occasionally prepared for the use of engineers. The sieves have sometimes as many as 120 wires in the inch, the very fine sizes of emery are however more commonly sifted through lawn sieves; but the finest emery that is obtained from the manufacturers, is that which floats in the atmosphere of the stamping room, and is deposited on the beams and shelves, from which it is occasionally collected. The manufacturers seldom wash the emery, which is mostly done by the glass workers, opticians and such others as require a greater degree of precision than can be obtained by sifting.

2.—Washing Emery by Hand.—Washing-over or elutriation, as the process is called by chemists, is a valuable application of the law of gravity to the chemical, metallurgical and mechanical arts. Thus the alluvial deposits of some of the tropical rivers are washed for the separation of the particles of gold they contain. A small portion of the mud of the river is stirred in a large quantity of water contained in a broad shallow basin, the gold being several times as heavy as the earthy particles quickly subsides, and the mud which remains suspended for a long period in the water, is removed by pouring off the water from the valuable sediment.

In a similar manner the particles of emery and other powders may be separated according to their magnitudes, in a more accurate manner than can be accomplished by sieves. A portion of emery powder of uncertain size is thoroughly well mixed in a large quantity of water, as in a common wash hand basin, and at the end of 10 seconds the liquid is poured off from the sediment which has fallen down in that period; the sediment is laid aside in a separate vessel. The bulk is again stirred and poured off at 10 seconds, and this second sediment added to the first, and this process is repeated until no further sediment is deposited in the period of 10 seconds; the process requires watchfulness and a steady hand. A fresh deposit is similarly collected from the residue after a longer period of rest, say 20 seconds, until the whole quantity of emery is divided into grains of so many sizes, as may be required for the particular branch of manufacture for which it is intended; thus—

3.—Emery for the Construction of Mechanism.—The author has been for many years in the habit of employing emery of twelve degrees of fineness, part of them prepared by himself by washing over, namely:

No. 1. Corn emery of commerce prepared by sifting
,, 2. Grinding ,,
,, 3. Fine grinding ,,
,, 4. Superfine grinding ,,
,, 5. Deposited at the end of 2 seconds.

No. 6.	Deposited at the end of	5	seconds
" 7.	"	10	"
" 8.	"	20	"
" 9.	"	60	"
" 10.	"	3	minutes.
" 11.	"	15	"
" 12.	"	60	"

The emeries of the sizes 5 to 12 are preserved in glass bottles, to prevent them from becoming accidentally mixed or contaminated with foreign substances.

4.—Emery for Optical Purposes.—Mr. Ross recommended mixing four pounds of the flour emery of commerce, with 1 ounce of powdered gum arabic, and then throwing the powder into 2 gallons of clean water. He collected deposits, as above described, at the end of 10 seconds, 30 seconds, 2 minutes, 10, 20, and 60 minutes, and that not deposited by one hour's subsidence was thrown away as useless for grinding lenses. The use of the gum arabic, which renders the water slightly viscid, was recommended by Dr. Green for preparing red oxide of iron, for polishing specula.

5.—Washing Emery in the Large Way.—Washing emery by hand as above explained is far too tedious for those who require very large quantities of emery, such as the manufacturers of plate glass and some others, who generally adopt the following mode:—Twelve or more cylinders of sheet copper, of the common height of about two feet, and varying from about 3, 5, 8 to 30 or 40 inches in diameter, are placed exactly level, and communicating at their upper edges, each to the next, by small troughs or channels; the largest vessel has also a waste pipe near the top.

At the commencement of the process, the cylinders are all filled to the brim with clean water, the pulverised emery is then churned up, with abundance of water in another vessel, and allowed to run into the smallest or the three inch cylinder, through a tube opposite the gutter leading to the second cylinder. The water, during its short passage across the three inch cylinder, deposits in that vessel, such of the coarsest emery as will not bear suspension for that limited time; the particles next finer, are deposited in the second or the five inch cylinder, during the somewhat longer time the mixed stream takes in passing the brim of that vessel and so on. Eventually the water forms a very languid eddy in the largest cylinder, and deposits therein the very fine particles that have remained in suspension until this period, and the water lastly escapes by the waste pipe nearly or entirely free from emery. In this simple yet elegant arrangement, *time* is also the measure of the particles respectively deposited in the 12 or more vessels, their number being determined by the quantity of sizes respectively required in the manufacture to which the emery is applied. When the vessels are to a certain degree filled with emery, the process is stopped, they are emptied, the emery is carefully dried and laid by, and the process is recommenced.

6.—Emery Paper is prepared like glass paper, and of about six degrees of coarseness. The powders sifted through the sieves with 30 and 90 meshes per linear inch being in general the coarsest and finest sizes employed. When

used by artizans, the emery paper is commonly wrapped around a file or a slip of wood, and applied just like a file, with or without oil, according to circumstances. The emery paper cuts more smoothly with oil, but leaves the work dull.

7.—Emery Cloth only differs from emery paper in the employment of thin cotton cloth instead of paper, as the material upon which the emery is fixed by means of glue. The emery cloth when folded around a file does not ply so readily to it as emery paper, and is apt to unroll, therefore engineers and others, give the preference to emery paper and emery sticks; but for household and other purposes, where the hand alone is used, the greater durability of the cloth is advantageous.

8.—Emery Sticks, are rods of deal about 8 to 12 inches long, planed up square, triangular, or with one side rounded like the half round file. Nails are driven into each end of the sticks as temporary handles, they are then brushed over one at a time, with thin glue, and dabbed at all parts in a heap of emery powder, and knocked on one end to shake off the excess, two coats of glue and emery are generally used. The emery sticks are much more economical than emery paper wrapped on a file, which is liable to be torn.

9.—Emery Cake consists of emery mixed with a little suet chopped small, rendered down, and mixed with a very little bees' wax, so as to constitute a solid lump, with which to dress the edges of buff and glaze wheels. The ingredients should be thoroughly incorporated by stirring the mixture whilst fluid, after which it is frequently poured into water, and thoroughly kneaded with the hands and rolled into lumps before it has time to cool. The emery cake is sometimes applied to the wheels whilst they are revolving; but the more usual course is to stop the wheel, and rub in the emery cake by hand, it is afterwards smoothed down with the thumb.

10.—Emery Paper, or Edwards' Patent Razor Strop Paper, had fine emery and glass mixed with the *paper pulp*, and made into sheets as in making ordinary paper. The emery and glass constituted together 60 per cent. of the weight of the paper, which resembled drawing paper except that it had a delicate fawn colour. This paper pasted or glued upon a piece of wood, and rubbed with a little oil was used as a razor strop. The patent for this invention was granted to the Rev. Mr. Edwards, in November 1843.

11.—Barclay's Artificial Emery Stone.—This material merits notice as the forerunner of the emery wheels now so universally employed; it was invented by Mr. Henry Barclay, who took out a patent in August, 1842, for combining powdered emery into discs and laps of different kinds, suitable to grinding, cutting, and polishing glass, enamels, metals, and other hard substances. The process of manufacture is described as follows:—

"*Coarse Emery Powder* is mixed with about half its weight of pulverized Stourbridge loam, and a little water or other liquid, to make a thick paste, this is pressed into a metallic mould by means of a screw press, and after having been thoroughly dried, is baked or burned in a crucible, muffle, or close receiver, within a furnace, at a temperature considerably above a '*red heat*,' and below the '*full white heat.*' In this case the clay or alumina serves as

a bond, and unites the particles very completely in a solid substance, called *Artificial Emery Stone*, which cuts very greedily, and yet seems hardly to suffer perceptible wear or destruction." "*Superfine Grinding Emery*, is formed into wheels in exactly the same manner as the above, but the proportion of loam is then only one-fourth, instead of one-half that of the emery: these emery stones, which are of medium fineness, cut less quickly but more smoothly than the above.

Flour Emery, when manufactured into artificial stones, requires no uniting substance, but the moistened flour emery is alone forced into the metal mould and fired, as some portions of the alumina present seem abundantly to suffice to unite the remainder. These fine wheels render the works submitted to them exceedingly smooth, but they do not produce a high polish on account of the comparative coarseness of the flour emery.

Stourbridge loam is by no means the only ingredient used in uniting the particles of emery, as many other substances answer as well; such as slate, Yorkshire gritstone, crocus, &c., and in this way the hardness and cut of the emery stone may be varied to a great extent."

Most of these emery stone grinders were formed with central holes, so as to admit of being attached to the lathe upon appropriate chucks or spindles; and the substance, it is said, is so porous as to absorb much water, which is gradually thrown to the surface by the centrifugal motion so as to keep the edge conveniently moist. Mr. Barclay made discs of various diameters from ¼ inch to 8 or 10 inches diameter, but the difficulty increased with the size, as the large were liable to warp and crack in the firing.

When the emery stone laps were required to have plane surfaces, angular or convex edges, &c., that could not be readily moulded, the composition was partially fired at a low heat, then turned in a lathe to the specific form, and the firing at a nearly white-heat completed the manufacture.

12.—Emery Wheels.—These invaluable additions to the stock of grinding tools, the practical development of the almost forgotten scheme referred to in the last article, are now met with in most workshops; and it would be difficult to assign limits to the range of purposes to which they apply. Primarily employed as simple grindstones for the repair of edged tools and for scaling and trimming castings and forgings before submitting these to the cutting tools in the lathe and planing machine, the emery wheel was soon found capable of far higher service, until, in many cases, it has nearly, and in some entirely, replaced the above named machines for numerous works in metal. For such purposes, the emery wheel, sometimes used dry, but more often moistened by a stream of water, is mounted to revolve at a high speed with its axis horizontal, vertical or at an angle, and is provided with a more or less simple arrangement of slides, tables and arbors to hold, traverse, and elevate the work; it is then the active part of a veritable machine tool,—some of which Emery grinding machines will be described in following Chapters,—and is employed for the faces and edges of rectilinear work, and for numerous cylindrical works. In other cases, as for sharpening the teeth of large saws, the emery wheel revolving in a moving frame is depressed to grind every

tooth; and for hardened steel, fluting and grooving, &c., emery wheels driven at speed on spindles mounted in the slide rest are applied to works themselves rotating in the lathe, or fixed between its centers; for all which purposes, under proper management, the emery wheel is remarkable for excellence of results, rapidity and economy.

Gum Emery Wheels.—Various methods and vehicles have been employed during the last 30 years to cement grinding, fine grinding, and flour emery for wheels of corresponding degrees of cut, and of large and small dimensions. Mixtures of gums melted and intimately combined with as large a proportion of one size of emery as they could bear without serious interference with their natural cohesion, much after the fashion of the little corundum wheels previously mentioned, were first employed for wheels of moderate size up to about 12 inches diameter; but they were found to "glaze" and then to rub or polish rather than to grind, and when used dry, the heat evolved partially melted the gums so that their edges had to be frequently repaired and wasted by turning, and the material proved unequal to the stress imposed upon it by the vigour of the work for which emery wheels have come to be employed.

Vulcanite Emery Wheels have their materials incorporated with a hard black substance similar to that used for electrical purposes; although far more durable than the "Gum Wheels," their edges also soften in use from the friction, this clogs and impedes the action of the emery and renders them more valuable for finer grinding, glazing and polishing than for the general purposes of the workshop.

The vulcanite base is mainly composed of the shreds and cuttings of waterproof garments, a good example of the utilization of waste products. The cuttings first boiled in soda to cleanse their fibrous exteriors, are amalgamated into irregular spongy sheets by being passed in bunches, again and again, between a pair of smooth iron steam-heated rollers. The result, called the "bond," in which all the silk and linen fibre is torn up and disappears, is cut into very small pieces and mixed with certain proportions of pure india rubber, lime, sulphur, linseed oil, and a large quantity of fine emery, and the whole ingredients are then thoroughly mixed by being many times passed vertically down between another pair of heated iron rollers, the surfaces of which become curiously scored and marked by the emery. The rough sheets produced are next "callendered," or reduced to uniform thicknesses, varying from one-sixteenth to half an inch, by long rolling with great pressure between a third pair of rollers. The warm material is then cut into discs, and placed in the moulds, flat iron plates with loose iron rings, kept heated upon a hot plate, from which the filled moulds, about a dozen at a time, are transferred to an hydraulic press, piled one upon another, and subjected to a pressure of from 300 to 400 lbs. to the square inch until cold. Lastly the vulcanite wheels are baked in the same manner as the stone wheels described in the following article, but at a much higher temperature and for a longer period.

The process of manufacture is exceptionally painstaking and tedious; and the material thus produced at Mr. A. W. Bateman's works, East Greenwich, is made into very tough true wheels up to 6 or 8 inches diameter, no thicker

than the sixteenth of an inch. The larger wheels up to 3 feet diameter by 12 inches thick, are composed of numerous stout layers superposed in the mould, with special precautions for their ultimate perfect adhesion, and for the exclusion of all particles of air as every layer is laid upon its neighbour; after which the whole is forced into one solid mass with heat and hydraulic pressure.

STONE EMERY WHEELS, which under various names are those most used, are made of all sizes and degrees of coarseness, all have the emery incorporated with lime, sand and other materials chemically cemented together by mixture with silicate of soda. This variety originated with Mr. F. Ransome, who also used a similar process for cementing together the sand for his *artificial grindstones*, patented in 1867, which see, WHEELS, article 33.

The materials, their proportions and precise details of manufacture, vary rather widely, thus, among others, the Standard Emery Wheel Co. employed by measure, 2 parts powdered chalk, 1 part lime, 4 parts Portland cement, 1 part finely-sifted lamp black, and 4 parts silicate of soda to 30 to 40 parts of emery. Mr. Batĕman employs Portland cement, powdered chalk, Maidstone sand, a natural silicious sand also found in Kent, silicate of soda and emery, in the proportion of 8 lbs. of the last to about 2 lbs. of the other materials mixed; the lamp black, the colouring matter is omitted as deleterious.

The thorough incorporation of the materials is all important and is effected in a machine, the details of one patented by Mr. Gubbins are as follows:—An oblong iron box with one hinged or fall-down side, to more easily remove the mixing, runs upon four wheels on a horizontal slide upon which it receives a reciprocating traverse by a link connected to an eccentric, and the spindle of the latter, mounted in the framework of the machine, carries a large spur wheel which is driven by a pinion on the main driving shaft. The solid side of the mixing box is pierced with a long narrow slit at about the center of its height, to admit the ends of two spindles mounted in the frame of the machine, which drive one another by spur wheels, in the proportion of four to five, the larger of which is driven by a second pinion also placed on the main driving shaft. The ends of the spindles within the box each carry a double ended paddle, something like the blades of a screw propeller, but attached to them to stand obliquely at an angle of about 45°; the latter, therefore, revolves at different speeds and in opposite directions, while the box and its contents travel slowly to and fro throughout the mixing. A simpler machine is, however, more general; in this a pair of thin-edge runners, about 2 feet 6 inches diameter, with numerous short crossbars cast in the solid upon their peripheries, revolve in an open conical iron pan, and a pair of scrapers attached upon either side of the cross-head carrying the runners and set at an angle to the vertical spindle, scrape the latter and the bottom of the pan. The mixed materials are withdrawn through a trap-door low down in the side of the pan. In mixing, the emery is first placed in the machines, then the other materials, and the silicate of soda last, and if the compound prove too "fat," that is, insufficiently solid, more emery is added. The quality of the silicate of soda, and also hygrometric variations are found to influence the result, the necessity for the addition is therefore a matter depending upon

practical experience. The materials when mixed soon commence to set or harden, hence several small mixings are made per day, just sufficient to keep pace with the consumption of the number of men employed in moulding.

The moulds for the smaller wheels, from about 2 to 12 inches diameter are smooth-bored iron rings or cylinders, according to the thickness of the wheels, with false bottoms fitted therein and provided with iron pins to give the central hole. The larger moulds are heavy turned iron plates with a central aperture to carry the different sized pins or cylinders to give the hole in the wheel, and are rebated down around their peripheries to receive iron rings to give that of the wheel; for the larger sizes these rings are made in halves with ears for bolts to hold them together, for their easy separation and removal after the wheel is moulded. The cores for large apertures, as for discs and crown wheels, &c., are frequently made of plaster of Paris turned true in a lathe, these give an exquisitely true smooth hole; they are left in the wheel until that has set, but are so tightly held by the contraction in drying that they have to be chipped out with the chisel and hammer. The material while still plastic is carefully packed in the moulds a small quantity at a time, worked all over and pressed down with the rounded end of a piece of broomstick about 2 feet long, held in both hands and against the shoulder. The stick is partially twisted round at every stroke to spread and interlace the grains of emery sideways as well as downwards, and its end is frequently cleansed by a similar stroke in an iron pot containing cotton waste and water. The excess of material is partially trimmed off with a trowel, after which the exposed surface of the emery wheel is flattened and smoothed by hand with a heavy iron roller, greased with a mixture of wax and tallow in turpentine. With wheels of moderate thickness and up to about 12 inches in diameter, the top of the mould is then covered with a piece of sheet iron and the whole turned over and the bottom and ring removed, the loose top plate is then dextrously turned over and the moulded wheel dropped flat on a slab, where it remains to harden. Larger wheels, too heavy for this treatment, are left in their moulds to set. The material becomes so hard in 24 hours that it will no longer indent with some pressure; after standing 3 days the wheels are broached out in their holes, mounted on spindles and their edges and rolled surfaces turned true with one of Brunton's revolving disc tools or a carbonate diamond tool, prior to being baked from 14 to 30 hours in an oven heated from 180° to 300° Fahr.; a large number of wheels are baked at a time, stacked one upon another with thin layers of sand between. Lastly, the wheels are smooth turned with a diamond tool, and mounted on spindles, are tested for soundness by being driven at about twice their working speed. The machine for this purpose stands in a corner of the workshop, its two exposed sides enclosed by a strong iron cage to catch the fragments of any wheels which fly to pieces; this precaution is not always considered necessary, and Mr. Evans, the manager, says, that out of 8,000 wheels personally tested by him at Mr. Bateman's works, the small number of seven only have broken under trial.

Stone emery wheels are made of all degrees of fineness irrespective of their size, the coarsest qualities are usually those of the larger dimensions, but these

large wheels are sometimes made of fine emery; the emery employed ranges in size from No. 4 to No. 120, that is, crushed and sifted to sizes which will pass through sieves having such numbers of holes to the inch. The wheels are commonly made of all diameters rising from 2 to 36 inches, and of thicknesses which vary from one-eighth to 4 inches for those from 2 to 12 inches diameter, from half to 4 inches for those from 12 to 24 inches diameter, from three-quarters to 6 inches for those from 24 to 30 inches diameter, and from 1 to 9 inches, but occasionally to 12 inches, for those from 30 to 36 inches diameter. Among the smallest of the abovenamed, therefore, some may be considered cylinders rather than wheels, and similar cylinders of larger sizes are made for special purposes. Another variety of wheels, termed *emery discs*, flat rings usually of moderate thickness compared with their diameter, have very large central apertures by which they are mounted upon flanges or collars formed in the solid with their spindles; these are used in machines for surfacing, with the work applied to their sides as laps, or cutting by their edges. Crown wheels are similar but deep hollow cylinders; these mounted in chucks revolve on the end of a mandrel as in a lathe, and the work fixed on a slide is traversed across their annular faces.

To obtain their full effect it is requisite to drive all emery wheels at a considerable velocity, usually at from 3,000 to 4,000 feet of surface speed per minute; although sometimes driven at a greater pace, the spindles of wheels of the undermentioned diameters are generally run at about the following numbers of revolutions per minute, viz., 3 inches diameter at 5,000 revolutions,—4 inches at 3,700,—5 inches at 3,000,—6 inches at 2,400,—8 inches at 1,800,—10 inches at 1,450,—12 inches at 1,200,—14 inches at 1,000,—16 inches at 900,—18 inches at 780,—20 inches at 700,—24 inches at 600,—30 inches at 500,—and 36 inches at 400 revolutions per minute. Careful mounting for the prevention of accident is necessarily essential for these rates of speed; the hole in the wheel, therefore, should fit the spindle, not tightly but without shake, and the wheel should in all cases be held between large flat flanges, the one in the solid with the spindle, and the other secured upon it by a washer and nut, with interposed packing, canvas or leather washers, between the wheel and the flanges.

The edge of the wheel usually wears fairly true circumferentially, and also as to its sides; so soon as it loses the first condition that should be reinstated by turning with a carbonate diamond tool, see Diamonds, article 7,—applied in a sliderest or used by hand; the hand tools are also employed to turn the edge to angular or curvilinear profiles, sometimes required. Should the wheel so far lose its truth as to become lopsided, it runs risk of fracture.

Emery Glazing Wheels.—The property of too readily glazing, one cause of the abandonment of the earlier emery wheels, has in a modified degree been turned to account for the production of emery polishing wheels; these, which are made only of moderate sizes, are composed of cork dust, shellac, india rubber, sulphur and flour emery. The performance of these wheels is favourably reported on.

13.—Emery Band Grinders.—These are flat strips of leather or stout canvas or inelastic woven endless bands, charged upon one surface with glue and coarse

emery after the same manner as buff wheels and emery cloth, stretched to run around two or more pulleys. Small common works such as brass cocks and similar castings, which are ground to clean and rough polish their exterior surfaces, are held on the rapidly running band in the fingers. Emery and oil are applied to renew the cut from time to time, and worn bands upon which the emery has become crushed from use, are like the cutlers' semi-worn buffs sometimes used for finer finishing. See also Chapter IV., section 2.

EMERALDS.—These valuable stones, the finest of which are found in Peru, are considered to be very soft gems, in consequence they require more than ordinary care in their polishing, and still do not admit of such acute angles and edges being given to them as to many of the harder gems. The Emerald is worked just like CARNELIAN.

ENAMELS.—These are metallic surfaces covered with a thin coating of glass of various colours, which is sometimes partially transparent, but generally opaque. The enamel or glass is ground to powder, mixed with some vehicle, such as turpentine, or oil of spike, and spread on as a thick coating of paint, and when dried, the whole is heated just sufficiently to fuse the enamel, and cause it to adhere to the metal. The work is placed within a muffle, which is in many cases a miniature arched vault open at one end, placed in the midst of a small furnace, and surrounded by burning fuel, which keeps it at the red heat, although the fuel cannot possibly touch the work. In other cases the furnace is made of sheet iron; it then measures externally about 20 inches long, 12 wide, and 10 deep, and is mounted on wrought-iron legs that support it, so that the opening or door, which is at the one end, may be on the level with the eye of the artist, whilst from the opposite ends proceeds the flue leading into a chimney. The whole apparatus bears some resemblance to a German stove, or rather, to a laundry stove considerably elevated, but the muffle, or a heated chamber corresponding therewith, is always provided for the reception of the work to be enamelled to protect the same from the flame and smoke of the fuel.

Many of the enamelled works can hardly be said to be polished artificially, as the lustre is produced simply by the process of fusion; thus the enamelled faces of watches, when the ground has been fired, only require the figures to be added, as the vitreous surface is mostly smooth enough from the fusion without being polished; and in less favourable cases the work is only ground to a level but dull surface, and afterwards just raised to the melting point, so as to fuse the surface, and thereby give it the polish.

The backs of gold watches and numerous articles of jewellery, including mourning rings, are so enamelled as to show various devices or inscriptions in gold, upon a ground or general surface of enamel; in this case the work is engraved, all the parts where the enamel is to appear being cut away by the graver, and the spaces are afterwards filled in with the pulverised enamel, which is burnt in, and lastly, the whole is polished down to a uniform surface.

Formerly nearly all the enamelled works were polished by the lapidaries, who used, 1st, the horizontal lead mill with fine emery for grinding; 2ndly,

lead with rottenstone and water; and 3rdly, the leather lap or buff wheel with putty powder. But the enamellers of the present day mostly polish their own work, and employ either an ordinary lathe with a mandrel upon which the laps are screwed like chucks, the cylindrical edges of the laps being alone used, or else they employ a polishing lathe similar to those of cutlers and others. The French enamellers commonly select instead of emery, a hard white pulverised porcelain, called white emery, which is manufactured at the Royal Manufactory of Porcelain at Sèvres, and they afterwards polish with yellow tripoli; the first is applied on a lead or wooden wheel, and the latter on a buff.

When enamels are polished by hand, the work is first roughed down with slips of water of ayr stone and water, used after the manner of a file; after which the different artists use slips of boxwood, mahogany, or metal, first, with pumice-stone, and then with crocus, nearly as for gold.

FACETS, a few words are given on the cutting of the facets or gems at the conclusion of the article on Carnelian, and the subject is considered more at length in the chapter on lapidary work.

FAYRER'S SWING HONE.—This is a flat and parallel slip of brass, in form like a hone, but with pivots at the ends by which it is suspended in two notches, so that this metal lap, or factitious hone, may accommodate itself to the angle at which the razor or other instrument is applied to it. The one side of the brass is first used with fine oilstone powder and oil, afterwards the second side with pulverised water of ayr stone and oil, and the razor strop is afterwards resorted to.

FELSPAR.—The fine varieties of this siliceous mineral, display most beautiful and varied iridescent colours; namely, blues and green in the Labrador Felspar, a beautiful apple green in the Amazon Stone, and a pearly white in the Adularia or Moonstone, the colours are best seen when the specimens are polished, which is effected as with Carnelian although Felspar is scarcely so hard.

FELT or Felted Cloth is very much used for polishing, especially for marble. *See* Cloth and Marble.

FISH SKIN is the skin of the Dog Fish, and some others, which is dried as its only preparation. The scales of the skin are hard and pointed and stand up obliquely, so that they cut or abrade very effectually in the one direction, but not in the other. Fish skin is more durable but less generally convenient than glass paper, to which it probably gave rise. It is now but little used in polishing, although in clearing off rounded and irregular works, as in pattern making, from the fish skin being somewhat rigid, when bent round the finger it may be almost used as a file, and it has the further advantage of leaving nothing behind it, whereas, glass paper commonly deposits some of the particles of glass in the surface of the wood, to the detriment of any tools subsequently employed. The fins should be selected for fine works.

FLANDERS BRICKS, these also known as Bath bricks, are made in large quantities of a clay found at Bridgewater, which contains a considerable proportion of fine sand. Besides the extensive employment of these bricks for domestic purposes, and in making founders cores, they are sometimes employed when rubbed to powder, in polishing bone, ivory, and soft metals, and also in dressing cutlers dry buff wheels, boards for cleaning table knives, &c. Trent sand is preferable when it can be procured.

Scraped or finely powdered Bath brick, equalized for size by being passed through a muslin or fine hair sieve, and the product kept in stoppered bottles to prevent the access of dust, is used in the preparation of boxwood blocks for wood engraving. The polished surface of the block does not readily take the finer pencil lines of the drawing, and whilst the draughtsman cannot enforce lines without the hard pencil point scoring the surface, the polish of the latter contends with that of the black lead and fatigues the eyes of the designer and of the wood-cutter. The common mode is to deaden the surface before drawing with one or two washes of flake white water-colour; this somewhat raises the grain, objectionable for a delicate drawing, and the pigment being a metallic oxide dulls the points of the gravers. For the best wood cuts the surface of the block is rubbed with a small quantity of the powdered Bath brick applied with a small copy of the list rubber employed for French polishing and used after the same manner; this dulls the surface, which is already too smooth to retain any of the powder, and leaves a good *key* for the pencil or other drawing.

FLAT SURFACES.—The principal modes of grinding flat or plane surfaces, will be described in Chapters IV. to VI.

FLINT.—This material is seldom polished, when required it is treated by the lapidary like Carnelian. Formerly the widest uses of flint were domestic for striking fire, and for gun-locks, both entirely superseded; it still, however, enters largely into the composition of porcelain and has given the name to *Flint* glass, in this latter it is now replaced by the more available substance, pure white sand obtained from Alum Bay, Isle of Wight, Maidstone and elsewhere. Flint is employed in the mechanical arts as the "bouldering stone" for rubbing down to a smooth face the laps, buffs and glazing wheels of the cutler. Calcined pulverized flint, sifted to sizes like emery, has also been employed glued upon wheels and rubbers for giving an exceptionally fine finish to models of crystals and other small works in wood, mentioned again under the heads GLASS PAPER and WHEELS, article 61.

2.—FLINT is also largely employed as the basis of silicate of soda, for the manufacture of which see SILICATE of SODA.

FLUOR SPAR.—This substance from the confusion in the arrangement and the frangibility of its crystals, requires a peculiar and careful treatment whilst being turned into form, described at page 168–9 of the first volume. The smoothing and polishing are conducted almost the same as in marble, but as fluor spar requires a longer continuance of the polishing process, it demands

considerable care to preserve the square fillets of the work from being rounded in the polishing, and with this object the powders are sometimes applied on small square slips of metal or wood, the sides of which are used somewhat as a file so as to present a superior degree of definition and permanence in the form of the polishers than would be obtained by the exclusive use of cloth applied with the fingers.

The lapidary pursues the same method in polishing fluor spar as carnelian, but he does not succeed so well as the Derbyshire workmen, and only produces what may be termed "a greasy polish."

FREESTONES.—Few or none of these admit of being polished, but many of them are rubbed smooth; the rubber being in general a smaller piece of the same kind of stone, sometimes used alone, at other times with a plentiful supply of sharp sand and water. In turned works, the stone rubber is smaller and held in the hand, the process being frequently conducted dry, and without additional sand. The freestones are also extensively turned, surfaced and semi-polished by the machines described. Chapter V.

GANNISTER STONE a species of slaty-stone somewhat resembling the Charnley Forest, or Mount Sorrel stone, is abundantly used in repairing the macadamized roads around Sheffield. When calcined, pulverized, sifted, and applied on a straight buff stick of the bull neck leather, the Gannister stone is preferred to most other materials for smoothing the threaded shoulders of pocket knives after they have been filed, as it is considered better to preserve the keen threads or projecting ridges of the shoulders than other abrasive powders. The work is completed on a wheel brush fed with fine emery and oil, followed by another with crocus and oil.

GARNET or ALMANDINE, a brilliant deep red coloured gem composed of alumina, silex and oxide of iron; found in Brazil, Ceylon, etc., the best in Bohemia, and the largest stones in the Tyrol. Garnets in which the oxide of iron is replaced by lime, magnesia, manganese, chromium, etc., separate or combined, are of different shades of green, brown, yellow, violet and black, some being rare.

Faulty portions are split off the stones in the lines of their cleavage by blows with a hammer, and the garnets are then generally worked by the lapidaries like Carnelian. In Prague, where great quantities are cut and sold for mounting in jewellery, the stones are ground and cut into facets on lead laps with emery, and then polished on copper laps with rottenstone; for the large stones when cut and polished *en cabochon*, or with rounded faces, and then called carbuncles, wood laps are used for the powders.

GERMAN HONE.—*See* HONE SLATES, also the article on setting razors in Chap. II.

GLASS is polished in various different manners, which are elsewhere particularized. Thus Plate Glass, is roughed with sand, smoothed with emery, and polished with crocus. *See* Chap. VI. Glass Lenses, are roughed out with sand,

figured with emery, and polished with putty powder. *See* Chap. VIII. Cut glass for household purposes and toys, is roughed with sand, smoothed on a Lancashire grit-stone, then with pumice-stone, and lastly is polished with putty or rottenstone. *See* Chap. IX.

Lapidaries in cutting glass for jewellery adopt the mode described in this catalogue as used by them for alabaster, with the exception that they omit the wooden mill.

Glass is used as a vehicle for polishing powders by watchmakers, watch-jewellers, and some others. *See* Brass, article 6, and Machinery, article 13.

GLASS PAPER.—In making this useful material, the fragments of broken wine bottles are carefully washed to remove all dirt, the glass is then crushed under a runner, and sifted into about eight sizes as in manufacturing emery. The paper is brushed over with thin glue, and the pulverized glass is then dusted over it from a sieve, which completes the process. Sometimes two coats of glue and glass are applied, or venetian red is mixed with the glue to give that tint to the glass and sand papers, and thin cotton cloth or twill is also used instead of paper, as the vehicle for the glass.

Flint, pulverized and sifted to sizes in like manner, is sometimes glued on the cloth or paper instead of glass. The finely powdered flint is also used alone, like other polishing powders, it is sometimes known as "Silica."

GLAZERS, or Glazing Wheels.—Wooden wheels covered with leather when charged with fine emery receive the above names, but when supplied with crocus and used for finer purposes they are called polishers. Such wheels charged with emery cake, bouldered and waxed to deaden the emery are much used at Sheffield. *See* Wheels, articles 52 and 53.

GOLD is generally polished in much the same manner as silver, although some variation is made as works in gold are generally much smaller and do not require such active means as those in silver.

1.—Gold is 1st polished with water of ayr stone in the stick used with water, 2ndly with slips of wood with coarse crocus, and 3dly with a buff stick and fine crocus or rouge. The black polish which is so much esteemed, is given with the naked hand and rouge, but the perfection of the polish depends on the peculiar texture of the skin, as the hands of some individuals do not at all answer the purpose.

2.—Flat Works in Gold are treated by cutlers and others 1st with water of ayr stone in the stick with water, 2ndly charcoal in the stick with water, 3dly box-wood and rouge very nearly dry.

3.—Cut or Facetted Gold is wrought upon pewter laps with crocus, the process closely resembles the cutting of facets on gems, *see* Chap. X., but the work is guided by the fingers alone.

GRANITE.—A hard crystalline compound rock composed of felspar, quartz, and mica, the preponderance of each mineral being usually in the above named order. General colours, gray, red and greenish; quarried in Cornwall, Devonshire, and Aberdeenshire.

1.—Granite Worked by Hand.—In quarrying; deep vertical, horizontal or inclined holes, according to the position of the block to be detached from its bed, are made at close intervals to receive the blasting charges, by percussion with steel chisel ended rods driven by blows of one or more men with sledge hammers, or by "jumping"; processes further described in Chap. V. The detached blocks are then roughly shaped, first by making a series of shallower holes about 6 inches apart along the intended lines of separation; these are then filled with steel wedges and pieces of iron, which are uniformly driven in until the stone splits. Secondly, the faces are partially levelled with heavy chisel edged hammers, followed by steel chisel, and the hand hammer. The more accurate dressing for building and other purposes is generally given by the mason with similar but lighter tools, under the guidance of wood squares and straight edges, after the block has left the quarry.

The dressed granite blocks are 1st ground to a moderately smooth surface by rubbing with a heavy iron plate fed with sharp sand or coarse emery and water; or in turned works, which are previously chipped and worked fairly cylindrical by hand, the granite is put in quick circular revolution against the rubber. 2ndly the work is smoothed with another iron plate and coarse flour emery. 3dly it is further advanced by wooden rubbers with fine flour emery, the rubbers being made the end way of the grain. 4thly and lastly crocus is used on thick felt laid on wood or metal. On account of the softness of the mica compared with the quartz and felspar, the hard rubber must be persevered with until near the conclusion of the polishing to keep the work flat, otherwise the mica is too quickly worn away and leaves minute hollows. Sometimes lumps of granite are used as rubbers instead of the iron plates.

2.—Granite Worked by Machinery.—The quarrying perforations are also pulverized by percussive rock boring machines, some actuated by springs and driven by hand, others by compressed air or steam after the manner of a steam hammer. Single machines mounted on weighted tripods are used above ground; in tunnelling and working within adits two or more are mounted on the cross bars of a travelling carriage to advance within the gallery. See also Chap. V.

Granite slabs are sawn from the blocks, but the process is necessarily slow and expensive. The soft iron or copper saw blades without teeth, used in the same manner as those for marble described later, are usually fed with coarse emery and water. The work has been much accelerated by the substitution of *iron sand* for the emery, a material patented by Mr. B. C. Tilghman in 1872. Small spheroidal grains or pellets of hard chilled cast iron, sifted to uniform sizes from about 40 thousandths to about one twentieth of an inch are preferred for granite, these roll under the saw scoring its edge and abrading the stone at the bottom of the saw kerf to powder; they are more active from not being themselves so easily crushed as the emery. Considerably finer grained iron sand is also used with good effect and is recommended by the inventor for use upon revolving and other grinders of cast-iron, wood, and leather. The hard cast-iron grains are produced by letting fall fine streams of the molten metal into a rapidly revolving saucer shaped iron disc, deflected from which they are

caught by a hood and drop into water. The material is manufactured by Messrs. Harrison of Middlesbrough, the largest size being about 75 and the smallest about 10 thousandths of an inch in diameter of grain. Hardened steel crushed to fine fragments very like emery in character, and similarly sifted to sizes through sieves of from 50 to 170 meshes to the inch, is made and used at Pittsburgh, U. S. A. for the same purpose, but is said here to bind or cake together under the saw and to be less effective than the iron sand. Granite is also sawn by reciprocating and circular saws armed with gem or carbonate diamond teeth, *see* Chap. XII., section 4.

MACHINERY to supersede hand work for turning and surfacing granite and other hard stone has made a more remarkable advance; for round dressing and turning the hand rubbers have been largely replaced, 1st, by carbonate diamond tools,—see Diamonds, article 7,—applied to the work by hand, or clamped in the slide rest, slowly traversed by the slide lathe. These tools which are indispensable for many curvatures and mouldings, etc., are much employed by Messrs. Farmer & Brindley and others. The abrading action of the diamond upon granite is unexceptionable, but the tool has the economic drawback of the necessity that the work should be first dressed fairly circular by other means, to at once permit the tool something approaching a continuous cut; otherwise excrescences abruptly catching against the diamond are apt to wrench it from its setting. 2ndly, by the interesting series of machines and tools for dressing, surfacing and turning granite directly and continuously from the *rough* blocks, patented by Messrs. Brunton & Trier, some of which are described in Chap. V.

3.—GRANITE CONGLOMERATE for paving. Granite for metalling roads introduced by Macadam, is too well known for more than allusion to the intention of the inventor, so seldom carried out, viz., that all the irregular broken cubes employed should be of a size to pass through a 2 inch ring; but the otherwise valueless debris from the general preparation of granite is now employed in the manufacture of artificial stone for paving and other purposes. The waste granite after being machine crushed, is screened in long revolving sieves with graduated apertures by which it is separated into sizes ranging from about one third of an inch to fine dust. The material mixed with lime and Portland cement and incorporated with a solution of silicate of soda is pressed into slabs from 2 to 6 inches thick and of all sizes to about 6 feet square for paving, and those laid in many populous districts in London show little signs of wear after long traffic; the artificial granite is said to be more durable and less costly than the natural freestone flags. A proportion of larger sized granite fragments with similar pieces of crushed quartz, are mixed with the finer in the manufacture of MACLEOD's Patent Granite Paving with a view to still greater durability. The finer powders only are employed by the CROFT GRANITE CONCRETE WORKS, LEICESTERSHIRE, in making "PATENT ADAMITE," a uniformly grained material which is pressed into moulds for bas-reliefs and numerous varieties of plain and decorated stone work for building purposes; including that of the house itself, which can be built of blocks and slabs grooved and tongued to fit into one another. GRANITE TAR PAVEMENT

is used for inexpensive and durable footpaths in most suburbs. Fragments of granite broken to a small size, from that of hazel nuts downwards, all used together, are mixed with common tar sufficient to thoroughly coat each stone; the mass while fresh is spread on the ground and raked to an even layer from two to three inches thick, and beaten flat with wood rammers. Allowed to remain one or two days to partially harden, the surface is finished with ordinary garden rollers. Wood floors and pathways are first thickly coated with tar and the mixed granite and tar is applied in two or more thinner layers, with time for each to partially harden.

4.—Granite, when worked by the lapidary is slit and roughly ground in the common mode adopted both with Carnelian and Alabaster, namely the slicer with diamond powder and the roughing or lead mill with coarse emery; afterwards it is found best to smooth it on a mahogany wheel with flour emery, and to polish it on the lead wheel with rottenstone; but it requires great care to prevent the soft mica from being unduly worn away.

GREENSTONE.—*See* Hone Slates, also the article on setting razors, Chap. II.

GRINDSTONE.—Grit Stones or Grinding Stones are varieties of sandstones, some of which are described.

1.—Newcastle Grindstones abound in the coal districts of Northumberland, Durham, Yorkshire and Derbyshire; and are selected of different degrees of density and coarseness, best suited to the various manufactures of Sheffield and Birmingham, for grinding and giving a smooth and polished surface to their different wares.

2.—Bilston Grindstone is a similar description of stone, of great excellence, it is of a lighter colour, much finer and of a very sharp nature, and at the same time not too hard. It is confined to a very small spot of limited extent and thickness, in the immediate vicinity of Bilston, in Staffordshire, where it lies above the coal, and is now quarried entirely for the purpose of grindstones.

3.—Carpenters' Rubstone is a hard close variety, used as a portable stone for sharpening tools by rubbing them on the flat stone instead of grinding. It is also much employed for the purpose of giving a smooth and uniform surface to copper plates for the engraver.

A much softer variety of sandstone, is usually cut into a square form from eight to twelve inches long, in which state it is used dry by shoe-makers, pocket-book makers, cork-cutters, and others, for giving a sort of rough edge to their bladed knives and instruments of a similar description.

4.—Devonshire Batts.—A porous fine-grained sandstone in considerable repute, from the quarries of Black Down Cliffs, near Collumpton.

5.—Yorkshire Grit is a variety not at all applied as a whetstone, but is in considerable use as a polisher of marble, and of copper plates for engravers.

6.—Congleton Grit is a very similar stone of a softer nature, and made use of by the same description of workmen.

7.—Sheffield Grindstone is a hard coarse grit stone used for grinding large

files, and similar purposes, it is obtained from Hardsley which lies about 14 miles north of Sheffield.

8.—Wickersley Grindstones are very generally used in Sheffield for most purposes of grinding, as knives, scissors, razors, saws, and edge tools generally. Wickersley stones are quarried at a village of that name about 9 miles east of the town of Sheffield.

9.—Sheffield Bluestone is a finer grained stone than either of the last two kinds, and is very generally used at Sheffield for finishing the grinding of articles of cutlery, that have been prepared on the Wickersley stones. The act of grinding on a blue stone is called "*whittening*" and the blades of table and pocket knives are always thus treated in Sheffield. The bluestones are found very abundantly in the neighbourhood of Sheffield at from ½ to 1½ miles on the north and south sides of the town.

10.—Artificial Grindstones.—These are made from cleaned sand and silicate of soda by the ingenious process patented by Mr. F. Ransome, 1867; further particulars of which will be found under Wheels, article 33.

GUM LAC.—*See* Lac; also Corundum.

GUN METAL is polished like brass, which *see*.

GYPSUM.—*See* Alabaster.

HACKING, a process employed in dressing rough grindstones, by notching or checkering the high parts with a hack hammer, which resembles a small adze of from one to three pounds weight, fitted with a short handle. The process is fully described under Wheels, article 15.

2.—The periphery or *face* of soft metal laps and wooden glaze wheels, are also in some cases hacked by the cutlers, with a very light sharp hammer, the edge of which should be as keen as a chisel, and used very delicately; but by far the more usual course is to score the edges of the wheels while they are at rest, with a pointed knife, which injures these tools less and entirely avoids the risk of spoiling the edge or angle of the lap, which should be scrupulously preserved.

3.—Lapidaries employ an entirely different mode of hacking or *jarring* their leaden, pewter, and copper polishing wheels, which are used with rottenstone and water, as fully described under the head Carnelian.

HARDWOOD.—*See* Wood.

HELIOTROPE.—*See* Bloodstone, and also the article on Carnelian.

HONE SLATES.—A mineralogical distinction for various slaty stones that are used in straight pieces or slabs for whetting or sharpening edges of tools subsequently to their having been ground on revolving grindstones.

1.—Norway Ragstone.—This is the coarsest variety of the hone slates. It is imported in considerable quantities from Norway in the form of square prisms, from nine to twelve inches long, and one to two inches thick, gives a finer edge than the sandstones, and is in very general use.

2.—Charnley Forest Stone is one of the best substitutes for the Turkey oil-stone, and much in request by joiners and others for giving a fine edge to various tools and also penknives. It has hitherto been found only on Charnwood Forest, near Mount Sorrel, in Leicestershire. The best Charnley Forest Stone, is by some considered to come *only* from the Whittle Hill Quarry, the other stones from the neighbourhood are more pinny, or present hard places.

3.—Ayr-stone, Scotch-stone, or Snake-stone, is most in request as a polishing stone for marble and copper-plates; but the harder varieties are also employed as whetstones. These stones should always be kept damp or even wet, to prevent their becoming hard.

4.—Idwall or Welsh Oil-stone is generally harder, but in other respects differs but little as a whetstone from the Charnley Forest. It is obtained from the vicinity of Llyn Idwall, in the Snowdon district of North Wales. For setting such tools as chisels and plane irons many workmen sprinkle the oiled surface of the Welsh and Charnley Forest stones with a pinch of flour emery.

5.—Devonshire Oil-stone is an excellent variety for sharpening all kinds of thin edged broad instruments, plane-irons, chisels, &c., and deserves to be better known. This stone was first brought into notice by Mr. John Taylor, who met with it in the neighbourhood of Tavistock, and sent a small parcel to London for distribution; but for want of a constant and regular supply, it is entirely out of use here.

6.—Cutlers' Green Hone is of so hard and close a nature that it is only applicable to the purposes of cutlers and instrument makers for giving the last edge to the lancet and other delicate surgical instruments. It has hitherto been only found in the Snowdon mountains of North Wales.

7.—German Razor Hone.—This is universally known throughout Europe, and generally esteemed as the best whetstone for all kinds of the finer descriptions of cutlery. It is obtained from the slate mountains in the neighbourhood of Ratisbon, where it occurs in the form of a yellow vein running virtually into the blue slate, sometimes not more than an inch in thickness, and varying to twelve and sometimes eighteen inches, from whence it is quarried, and then sawn into thin slabs, which are usually cemented on a similar slab of the slate to serve as a support, and in that state sold for use. That which is obtained from the lowest part of the vein is esteemed the best and termed old rock. The German Hone is now used almost exclusively for razors, as being very soft, it is cut by any instrument applied at an angle, and not laid flat down as a razor invariably is.

8.—Blue Polishing Stone is a dark slate of very uniform character, in appearance not at all laminated; it is in considerable use among jewellers, clock-makers and other workers in silver and metal for polishing off their work, and for whose greater convenience it is cut into lengths of about six inches and from a quarter of an inch to an inch or more wide, and packed up in small bundles of from six to sixteen in each, secured by means of withes of osier, and in that state imported for use.

9.—Grey Polishing Stone is a stone of very similar properties to the blue, but

of a somewhat coarser texture and paler colours. Its uses are the same and both kinds are manufactured near Ratisbon.

10.—WELSH CLEARING-STONE is a soft variety of hone-slate, the use of which is confined to curriers, and by them employed to give a fine smooth edge to their broad and straight-edged knives for dressing leather. They are always cut of a circular form.

11.—PERUVIAN HONE has been recently introduced as a whetstone, and is said to be imported from South America. It cuts freely with either oil or water, and is suitable for sharpening large tools that do not require a very fine edge.

12.—WELSH HONE. *See* article 4.

13.—OILSTONE WHITE AND BLACK. These are varieties of the Turkey and Arkansas stones. *See* OILSTONE.

14.—BOHEMIAN STONES are imported from Germany, and are used by jewellers in the same manner as the blue and grey polishing stones for polishing small works, such as the settings around gems. The Bohemian stones cut well, and keep a good point for small work.

HORN handles for razors, knives, and similar works when moulded (see Vol. I., page 125) are scraped and then buffed with Trent sand and oil, and afterwards with rottenstone and oil as more fully explained under the head Tortoiseshell; but upon the latter material the Trent sand is not used in its natural state, as it would be too coarse and vigorous in its action on that soft and expensive substance; for buffing tortoiseshell therefore the Trent sand is first calcined and pounded, and then passed through a muslin sieve. *See* article TORTOISESHELL.

Horn is sometimes used by watchmakers as a vehicle for the application of polishing powders to flat works. *See* MACHINERY, article 13.

HYACINTH.—*See* ZIRCON.

HYDROGEN.—Peroxide of, a limpid colourless liquid of about the density of water; prepared by decomposing with a suitable acid from peroxide of barium, after which the insoluble barium precipitate is removed by filtration leaving the peroxide of hydrogen in solution; supplied commercially in glass carboys and wood casks containing from about 12 to 40 gallons. Employed for bleaching ivory, bone, fabrics, feathers, tissues, silk, straw &c. The ivory or bone if in strong pieces, such as table knife handles, is first soaked in a bath of dilute caustic soda, or if finished or delicate work in a similar bath of carbonate or silicate of soda, to remove all external grease; it is then immersed from 24 to 36 hours in the peroxide of hydrogen contained in an earthenware vessel, the liquor maintained at a moderate heat, about 70° Fahr., after which the ivory is allowed to dry slowly away from a fire. The peroxide bath varies from 12 to 15 vols. in strength, or contains from 12 to 15 times its own volume of oxygen available for bleaching; the former is usually employed, but the latter is preferred by some for bleaching ivory of very bad colour. A more active bath is obtained by the addition of 1 pint of silicate of soda to every 33 gallons of the peroxide. Wood or lead lined cisterns may also be used, but none of

iron, which metal must not come in contact with the ivory or liquor. The bleaching is cumulative and continues after the articles are removed from the bath from the action of the liquid they absorb, the pure white colour being only fully developed when the latter has entirely dried out. The peroxide of hydrogen attacks both the lime and the gelatine; better qualities of ivory which contain more of the latter become a uniform pearly white, but with inferior brown-hued ivory the bleaching is of more value, virtually obliterating all difference in the colour of its darker and lighter layers or fibres, indeed, the surfaces of all ivory thus bleached almost entirely lose their *life* or the distinctive markings of the grain.

Mr. E. Marsden, a Sheffield ivory cutter, soaks the knife handles in water on removal from the bath to prevent a fine crystalline exudation, which, however, he says, often reappears on drying if this washing be insufficient. Should one bleaching not produce a white colour he employs a second and sometimes a third similar immersion, and he considers the ivory is in no way deteriorated by the process. Mr. Bower of London, on the other hand, finds this method inadvisable for the thinner pieces of ivory used for combs, the teeth of which then are liable to break away in cutting, for such thin delicate works he prefers bleaching by sunlight, the best procedure for which for carved ivory and works in ornamental turning is given page 22, Volume V.

Mr. J. H. Paul, B.Sc., of the Albion Chemical Co., Woodside, S.E., recommends the employment of a solution of 5·37 grammes of pure permanganate of potash in one litre of distilled water, and a mixture of one part of pure sulphuric acid to four of water, for testing the condition of the bath, to determine the proportion of peroxide abstracted by any batch of material bleached, so that the precise strength of the bath desired may be restored by corresponding additions. The apparatus consists of a burette, a graduated glass tube terminating in a stop cock, for measuring the standard solution of permanganate, a pipette graduated to measure 2 cubic centimètres, 4 c. c. and 40 c. c. exactly, and a glass beaker to contain about 150 c. c. Two cubic centimètres of the liquid to be tested are taken from the bath in the pipette and transferred to the beaker, then 40 c. c. of water and 4 c. c. of the dilute sulphuric acid are added and all stirred together with a glass rod; the beaker is next placed under the burette filled to zero, from which the permanganate is permitted to fall drop by drop. Mr. Paul says,—"As this takes place oxygen is given off and the permanganate loses its violet colour so long as there is any undecomposed peroxide of hydrogen in the beaker, when, one drop more causes the liquid to become permanently pink. Directly this occurs the tap is turned off, and the graduations on the burette read again; the difference between the two readings shows the quantity of permanganate required for 2 c. c. of peroxide. Hence the number of c. c. of permanganate divided by 2 gives the number of volumes of oxygen available for bleaching; thus, suppose 24·2 c. c. of permanganate have been used, it shows the vols. of oxygen to be $\frac{24\cdot2}{2} = 12\cdot1$, or the peroxide to be of 12·1 strength. The per-

manganate solution should not be kept beyond one month after which it is liable o lose strength. The strength is so arranged that every c. c. of permanganate solution exactly corresponds to 1 c. c. of oxygen measured at 60° Fahr. under ordinary atmospheric pressure."

Peroxide of hydrogen used for bronzing, *see* Chapter XIII., Section 3.

IDWALL STONE.—*See* HONE SLATES, article 4.

INDIA RUBBER OR CAOUTCHOUC, the sap of the Ficus elastica, a native of South America and East India; imported in irregular shaped masses as collected from the trees. Cleansed, and impregnated with sulphur after mastication, and formed into sheets, the resulting VULCANIZED india rubber is extensively employed for washers and other elastic packing in machinery, for tubes, springs and numerous other purposes. Subjected to great heat during its mixture with larger proportions of sulphur it forms the strong, hard, black homogeneous substance EBONITE or VULCANITE, which, pressed into blocks and slabs in moulds is used for many purposes and especially as a non-conductor in electrical apparatus. Vulcanite is worked after the same manner as hard wood, and receives a dull greasy polish with felt rubbers and rottenstone, or other similar powders and oil.

2.—A small quantity of finely ground glass or emery mixed with the gum during its incorporation into vulcanized india rubber, is another variety; slips of this material inlaid in cedar as pencils, or simple pieces, are used by draughtsmen and as writing ink erasers. The powder diminishes the cohesion of the gum, the two disintegrate in use and their particles roll together between the tool and the surface of the paper, the elasticity of the one preventing too active abrasion by the other, hence they cleanse without injury to the surface acted upon.

3.—SPONGY or cellular india rubber, another vulcanized preparation, a fabric full of irregular air holes, soft and elastic as a natural sponge, is made in small rectangular blocks, often valuable for the application of polishing powders dry or with water or oil.

4.—INDIA RUBBER or the waste cuttings of waterproofs is employed in the manufacture of some of the finer grained or glazing emery wheels used for polishing. *See* EMERY WHEELS, article 12.

IRON.—The modes of polishing the parts of machinery made in wrought and cast-iron, are described in the general article MACHINERY in this Catalogue. *See* also WROUGHT-IRON and CAST-IRON.

IRON STONE.—A straight slab of the hæmatite iron ore, ground flat on the one face, is sometimes used by the Sheffield cutlers after the yellow German hone, in polishing the "*cannell*" or chamfers made by the German hone in setting razors.—The iron stone is very hard, and leaves a very smooth edge, almost fulfilling the purpose of the razor strop, but it must be used very lightly and sparingly. *See* the article on setting razors, Chap. II.

IVORY.—The modes of polishing objects made of this useful and ornamental substance, differ according to the nature of the works; and although the remarks here offered refer especially to the ivory of the elephant, that of the tusks of other animals, also the corosos or vegetable ivory and bone are treated nearly or quite the same, when applied to similar uses.

TURNED WORKS.

1.—TURNED WORKS with plain surfaces may generally be left so smooth from the tool as to require but *very little polishing*, a point always aimed at with superior workmen by the employment of sharp tools. In the polishing of turned works very fine glass paper is 1st used, and it is rendered still finer and smoother by rubbing two pieces together face to face; 2ndly, whiting and water as thick as cream is then applied on wash leather, linen, or cotton rag, which should be thin that the fingers may the more readily feel and avoid the keen fillets and edges of the ivory work, that would be rounded by excessive polishing; for the best works the whiting should be washed before use to remove the gritty particles usually found therein, in the manner described for washing emery; 3rdly, when the work feels smooth, or to hang less to the rag than at first, the work is washed with clean water on the same or another rag; 4thly, it is rubbed with a clean dry cloth until all the moisture is absorbed, and lastly a very minute quantity of oil or tallow is put on the rag to give a gloss.

Scarcely any of the oil remains behind, and the apprehension of its being absorbed by the ivory and disposing it to turn yellow, may be discarded; indeed the quantity of oil used is quite insignificant, and its main purpose is to keep the surface of the ivory slightly lubricated, so that the rag may not hang to it and wear it into rings or groovy marks. Putty powder is sometimes used for polishing ivory work, but it is more expensive and scarcely better suited than whiting which is sufficiently hard for the purpose.

Ivory is also sometimes polished with *Dutch rush* applied in the manner for WOOD, article 5, and at page 471, Vol. IV.

2.—TURNED WORKS consisting of many parts are best polished separately, as they are then more accessible, and the whiting and water do not penetrate and clog the joinings of the several parts, and prevent their easy separation. Accurate workmen frequently polish screw threads, in order to make them move the more easily, and to endure the longer without wearing loose; this is sometimes done with screws in ivory and the woods, as well as those in the metals, and is to be highly recommended.

3.—TURNED WORKS ornamented with the eccentric chuck or revolving drills and cutters should, in the first place, be cut with exceedingly sharp tools, which have been not only ground but also polished on their cutting edges in the manner set forth in later pages; in which case, the edge of the tool imparts a considerable degree of its own polish to the smooth cuts it makes upon the work, and but little polishing of the latter is then necessary.

Such polishing upon the decorated surfaces of ornamentally turned works

may generally be accomplished with a brush, like a long narrow nail-brush, with whiting and water, and lightly applied in all directions to penetrate every interstice. When more is required, or any roughness left by inadequately sharpened tools has to be removed, broad facets or other flat surfaces produced by the cutters, may be rubbed smooth and polished with the whiting and water applied on some small flat blocks of pine wood under the fingers, taking care that the rubber lies flat on the work. Flutes or other cutting sunk below the surface, are similarly treated with the ends of slips of the wood cut to their counterpart forms and dipped in the whiting and water; it is then necessary, however, to frequently renew the shapes of the ends of the slips as the fibres rapidly spread out in the form of a brush, in which condition they deteriorate the surface edges of the flutes previously left sharp and square by the tool.

After the polishing the work is immediately well cleansed in water with a softer brush to remove every trace of the whiting, wiped and pressed with clean linen or cotton rag to dry off the surface water, and then allowed to dry in the air or at a good distance from a fire; the complete evaporation of the water absorbed by ivory taking some hours. When thoroughly dry a gloss is given with a clean soft brush, over which a drop of neats-foot oil has first been rubbed with the fingers. The best practice is to do but little polishing at first and to repeat the process if necessary, rather than by injudicious activity, to round and obliterate the delicate points and edges of the cutting upon which the beauty of ornamental turning mainly depends.

FLAT AND FILED WORKS.

4.—Superior Flat Works are accurately filed and scraped, then cleaned with fine glass paper folded around a square stick, afterwards with whiting also on a stick of deal planed very flat and square and used as a file; some workmen cover the wood with one or two layers of flannel or cloth, but the naked wood, although somewhat tedious, will produce more exact surfaces and better defined edges.

5.—Common Filed and Carved Works are finished—1st, with Trent sand and water on flannel or a brush; 2ndly, scraped Flanders brick used in the like manner; 3rdly, wet linen or woollen rag with powdered chalk, which soon rubs down smooth, and to the condition of ordinary whiting.

6.—Razors and Knife Handles are generally finished by shaving or scraping, and 2ndly by buffing them on the wheels, as more fully explained under the head Tortoiseshell; but the following methods are by some preferred.

7.—Common Razor Handles.—These are sawn out and filed, then scraped with an old razor blade, called a shaving blade; two razor handles or scales are then held at the one end in a pair of clamps in the vice, and rubbed lengthways —1st, with chalk and water on felt or cloth, which cuts very quickly; and 2ndly with whiting and water for the finish.

8.—Best Razor Handles.—Two scales are slightly riveted together and buffed, 1st, on a buff wheel fed with Trent sand; 2ndly, buffed with rottenstone;

3rdly, they are *handed up* or polished with the naked hand and rottenstone. Other workmen entirely omit the rottenstone, which requires oil, and conduct the work with chalk and whiting, so that water may be used throughout the work.

9.—UMBRELLA AND STICK HANDLES, and many similar pieces are polished first with sand, and then with whiting, on cloth wheels consisting of several circles of thick cloth or felt, clamped between two smaller discs of wood; the cloth projects about an inch around the margin to make a soft elastic edge.

JACINTH OR HYACINTH.—*See* ZIRCON.

JADE, a tough compact translucent mineral, dark mottled green or grey white in colour, found in the beds of some rivers in China, in Siberia and in New Zealand, but not in Europe; some worked jade ornaments have been found in the ancient lake dwellings in Switzerland. It is polished by lapidaries like CARNELIAN but it only takes a greasy and not a brilliant polish.

JAPANNED WORKS.—Such of the japanned works as are baked in ovens, for the evaporation of the solvent of the varnish, are 1st forwarded with pumice-stone powder applied with water on list or flannel; 2ndly they are polished either with rottenstone or putty powder and oil, also on flannel; and 3rdly with the dry hand and rottenstone.

JARGOON.—*See* ZIRCON.

JASPER obtains just the same treatment as Carnelian in the Lapidary's art; it occurs of numerous colours and varieties, and is nearly equal to Agate in point of hardness.

JET is a soft bituminous mineral, and, like Cannel Coal, receives in the hands of the lapidary the same routine as ALABASTER; which see.

The articles on Jet and Cannel Coal (Vol. I., p. 162-3) describe an entirely different method of working these peculiar substances, and to which the reader is referred. *See also* CANNEL COAL in this Catalogue.

JEWELLERY.—*See* the articles on Gold, Silver, Enamels, and Saw-dust.

LABRADORITE, or Labrador felspar, a very beautiful mineral so named from having been first found in the Isle of St. Paul, on the coast of Labrador; composed of silica, alumina, lime, peroxide of iron and traces of other metals. Colour, a base of dark blue marbled and mottled with shades of blue and green, with streaks of brown and gold; less observable in one aspect, the various colours become lustrous or chatoyant when the polished surface is held at different angles to the light. Usually found in small pieces and used in jewellery and works of art, often antique; labrador is worked and polished like carnelian.

LAC or GUM LAC, in its three varieties Shell, Stick, and Seed lac, is a resin-like

substance produced by an insect on several varieties of trees found in Siam, Assam, Malabar and in Bengal. Colour, rich red brown; hard, brittle and translucent; almost completely soluble in alcohol. The incrusted twigs as gathered are known as stick lac; their coating coarsely pounded, washed in water and dried in the sun, as seed lac; and the same melted by heat and wrung through linen bags, the exuding drops of the resin falling and flattening into small thin scales on some smooth surface, becomes shell lac.

In India, among other purposes, it is used by the natives combined with corundum in the formation of polishing wheels and rubbers, *see* CORUNDUM; mixed with other materials and with emery it is also so used here, *see* EMERY, articles 12 and 13. Shell lac is extensively used in many manufactures and is the basis of a large proportion of the spirit polishes, varnishes and lackers for wood and metal, for which see Chapter XIII., section 1.

LACKER, the varnish mentioned above, employed in many varieties of colours and consistency.

LACQUER, JAPANESE.—A natural varnish, the sap of the *Rhus vernicifera*, indigenous to Japan. The full-grown tree has a straight smooth trunk 25 to 30 feet high, crowned with spreading foliage bearing pendulous bunches of small fruit, of which the stones contain a valuable wax; raised from seed and cuttings, cultivated throughout the Empire, more largely in the northern and central provinces and extensively at Yoshino, Aizu and about Tokio. Sap is taken after about eight years, the yield gradually increases and is at its full in trees from fifteen to thirty years old; thence it diminishes and the tree is usually cut down to grow again from its roots. The wood is much valued for its fine grain and gradation of colour, which shades off to nearly white from a rich gold hue at the heart. The stones of the ripe fruit are crushed, boiled in water and pressed to obtain the wax; considered superior to that produced by the *Rhus succedanea*, the vegetable wax tree of Japan.

Two qualities of the juice or raw lacquer, called Ki-urushi and Seshime-urushi, are obtained. The former, the more plentiful and valuable, is collected from June to November, as follows;—several shallow cuts about one inch apart are scored partially around near the bottom of the trunk and the sap, which exudes in drops from between the inner and outer bark, is scraped off with an iron hook-shaped tool; when the flow ceases a similar series of incisions is made on the other side of the stem about two feet higher up, and so on alternately upwards to the top. Both the *saving* and the *killing* systems are followed in collecting; in some districts the trees are tapped only every other year and but a moderate quantity of sap taken, that their strength may be unimpaired; in others, as in the lacquer grounds at Tokio, the killing process is employed, young trees are tapped every year and with more and closer incisions that the largest possible quantity of sap may be extracted; trees thus treated are rapidly exhausted. The inferior quality, seshime-urushi, is obtained from the prunings and loppings, the branches are cut in pieces, steeped in water, moderately heated and then subjected to pressure; it is used mostly and legitimately for the

underlying coats of lacquered ware. Commercial Ki-urushi is seldom pure as required for the best works, but is generally adulterated with some proportion of the inferior seshime; the dealers also generally add oil of *Perilla ocymoides* to the already mixed juice, and, if not in excess, it is found that this oil does not materially impair the natural drying properties of the Ki-urushi.

The pure sap is a grey-coloured thick gum-like fluid, which, when not continuously collected, flows and covers the bark below the cuts and rapidly darkens and dries by exposure to the air into a lustrous transparent varnish. Analysis made by Mr. S. Hiraga shows the pure juice to be composed of a resin, principally urushic acid 85·15, a gum, indistinguishable from gum arabic, 3·15, water and volatile matters 9·42, and a residue of colouring and nitrogenous matters, insoluble in water or alcohol 2·28. Ki-urushi, as commercially sold, mixed with larger proportions of gum, water and sometimes oil, usually contains but 58 to 70 per cent. of urushic acid. This main constituent when separated is a pasty dark coloured substance having the characteristic odour of the juice; readily soluble in benzine, ether, bisulphide of carbon and chloroform, but insoluble in water; unaffected by heat to 320° Fahr., but slowly carbonizing above 360° Fahr.; exposed to the air it does not dry nor show any signs of the changes peculiar to the juice from which it is extracted; it is highly poisonous and particularly irritating to the skin. Urushic acid combines chemically with nitrates of silver and copper, chlorides of iron and platina and some other metallic salts, used to vary its colour, and it is mixed mechanically with powdered metals, such as sulphide of mercury or cinnabar, and with several earths, clays and impalpably powdered stones for the same purpose and to give body. The drying property of the sap proves dependent upon the presence of the nitrogenous matter, which varies from 2 to even 8 per cent. in some samples; that which contains the most dries the soonest, but the varnish is then less lustrous. On the same subject Mr. Hikorokuro, chemist to the Imperial Government, says,—"A damp atmosphere appears essential to the action of the nitrogenous matter, as shown by a series of experiments in damp and dry air and gases, conclusions that bear out the experience of our lacquer men, viz., that lacquer dries most readily in the rainy season and better in summer than in winter."—The production of Japanese lacquer ware is noticed in Chapter XIII.

LAPIS-LAZULI, a dark coloured mineral with azure veins found in limestones and granite in India, Persia and Siberia; used in jewellery and by the lapidary. Large works, as with malachite, are made up of numerous pieces fitted and cemented together, or of its veneers fixed upon other stone. It was formerly precious as the only source of the beautiful pigment true ultramarine, now generally replaced by chemical materials. Lapis-lazuli is difficult to polish from its irregularity in texture, it abounds in soft places which wear away more rapidly than the general bulk of the stone; it is cut and polished like carnelian.

LAPS, metal polishing wheels. *See* WHEELS, articles 39 to 49.

VAS, which are worked for ornaments and specimens, do not generally admit of being well polished, being irregularly hard and soft, and also scoriaceous; they are worked by the lapidary just like ALABASTER, which see.

AD is the basis of many of the laps, and is rendered sometimes harder by the addition of variable proportions of tin and antimony; *see* WHEELS, articles 39 to 49, and Chap. VII.

Lead may be readily worked with *rasps*, but it clogs files so much as to render it difficult to produce a smooth surface by those instruments; in practice it is generally scraped for the smoothest surfaces. Lead is not often polished, it would require to be treated like pewter but with greater care, to prevent the formation of utters in the scraping or burnishing.

Lead when reduced to the white oxide, forms the commonest kind of putty powder, the process of manufacturing which is described under the head PUTTY POWDER.

ATHER.—The leather principally used for polishing, in the manufacturing towns of Sheffield and Birmingham, is the beast hide, or the leather of the ox as prepared for the soles of shoes, which is much softer and open in the grain before it is hammered for the latter use. The hide is usually cut into parallel pieces or strips, which are glued around the edges of wooden discs; then constituting buff wheels if charged with emery, and polishers if dressed with crocus; and the leather is also fixed on straight sticks known as buff sticks.

The leather varies much in thickness, that about the neck of the hide being sometimes nearly an inch thick, and very soft, this part being designated as *bull neck*, a material for which the thick hide of the sea cow or sea horse is frequently substituted.

Occasionally the curried hides of the horse, and other leathers used in making harness, are employed for buff wheels; and in the metropolis in particular, the thick buff leather of old regimental belts—now difficult to obtain—was much employed for similar uses, but although cheaper it is softer and far less durable. Wash leather, prepared from sheep skins split in two, is also much used in polishing, but mostly after the manner of a dusting cloth, or to prevent the hand touching the goods.

NSES.—*See* Chap. VIII., sections 2 and 3.

ME is occasionally used as a polishing material on account of its cheapness, as the only preparation required is to slake the lime with a little water, it then falls to a fine powder and which is sometimes sifted. Lime is used for polishing the commonest works in bone, such as brushes, and also for Albata Spoons.

A natural carbonate of lime received from Germany and known as CALSH, which see, is used for polishing Meerschaum. *See also* MEERSCHAUM.

MESTONES.—The substances to which this name is applied differ greatly in hardness and compactness. Some are so soft as not to admit of being

polished, and are treated much the same as the Freestones, (which see), whereas, those limestones which do admit of being polished, are generally designated under the name marble, the mode of polishing which is minutely described under that head.

LITHOGRAPHIC STONES, are a fine *oolite*, a peculiar kind of fine granular limestone, principally obtained from the interior of Germany.

The surfaces of lithographic stones are required to possess different degrees of smoothness, according to the subject for which they are employed. When the drawing is to be made at once upon the stone, a certain amount of roughness or granulation is necessary, or it will not so well abrade the lithographic drawing chalk, and this granulation is required to be more or less fine according to the kind of drawing. But much smoother surfaces are required for those stones upon which the transfer process is to be employed, as for lithographic writing, which is first executed on paper, and then transferred to the stone, by passing them together through the press.

Stones of moderate dimensions are first rubbed flat with the face of another smaller piece of lithographic stone, fed with sand and water, or better and more quickly with the *levigator*, a heavy flat iron disc, fed in the same manner and used as described Chap. V. The sand is prepared to different degrees of fineness by sifting, as explained under the head Emery, the coarsest sieves employed have about 80 and the finest about 120 wires to the inch. The stones for chalk drawing are more generally left from the sand of appropriate fineness, but some and those for transfer work are 2ndly, smoothed with a lump of pumice stone and water, but this smoothing is sometimes omitted, and are 3rdly, polished with the flat side of a piece of water of ayr stone also supplied with water. Large stones, sometimes nearly 5 feet square, are ground flat in machines, slowly travelling beneath a rapidly revolving iron disc, always of larger diameter than their widths, with sand and water; and are afterwards smoothed and polished by hand in the same manner as the smaller,—which last operation then requires still more skill to preserve the flatness of the printing surface and its necessary parallelism to that of the under side of the stone.

LOAM is used with water by some manufacturers as a cheap material with which to grind in the conical plugs of brass valves and cocks. Loam contains more silex than the generality of the clays, but these also are occasionally used for polishing common works.

MACHINERY Composed of Wrought-Iron, Cast-Iron and Steel.—The engineer and mechanist employ nearly the same routine for polishing these three materials, more particularly in turned works, in which the variations principally depend upon the degree of finish required. This general article is therefore intended to apply to all three materials; and some particular observations expressly suited to each of them, will be found under their respective heads of Wrought-Iron, Cast-Iron, and Steel.

TURNED WORKS.

1.—LARGE SIZED TURNED WORKS.—Such parts of machinery as come under this denomination are in almost every case turned in self-acting lathes, which, under proper management, leave the surfaces very exact and smooth so that many of them require no polishing whatever, a process reserved for those exterior parts which meet the eye, when the machinery is erected.

Heavy works are made to revolve with considerably greater velocity than that proper for turning, and they are polished with a long stick of deal 1 to 2 inches thick, and 2 to 4 inches wide, the end of which is cut off square. The stick is dipped into a shallow vessel containing oil, then into another with dry emery after which it is pressed forcibly against the work, never being allowed to remain long in one position upon the lathe rest. Occasionally, for additional purchase, a bent bar of iron is used, to the end of which is fixed a block of wood, in imitation of the hanging tools for turning iron, figs. 423 and 424, page 527, Vol. II. Sometimes a thick piece of leather is fixed on the end of the polishing stick for the application of the emery, of which two or at most three different-sized grains are used, namely, corn emery, grinding, and fine grinding emery.

2.—MEDIUM SIZED TURNED WORKS.—Many of these which are turned in power lathes running at a proportionate velocity, with tools properly formed and lubricated with abundance of water from a small jet, are left so smooth as hardly to want any polishing, or at most an inconsiderable amount of polishing with fine emery powder or emery paper; but in other works less skilfully turned by hand tools and with little or no water, it is usual to reduce any very trifling irregularities of surface to a general level, by means of a smooth file, slightly greased, which is rubbed lightly over the work as it revolves; careless workmen are apt however to rely too much on this practice, and having left the work full of ridges from the turning tool, to begin with a coarse file; this practice is detrimental to the production of good true work, and the preservation of the angles.

Works of medium size are polished nearly as above described, but with a deal stick chopped to a chisel edge, or to a square point and thrust against the work; sometimes instead of the point the side of the stick near the end is used as a crow-bar for additional purchase.

Generally two, but occasionally three sizes of emery are used, varying from grinding to flour emery; but it is necessary between the application of each powder, to wipe the work entirely clean with rags, cotton-waste, sawdust, moslings, (or the curriers' shavings of leather), and also to use a fresh stick, or to chop a clean point, for every kind of emery.

3.—SMALL SIZED TURNED WORKS.—For these, emery sticks, (those with emery glued upon them,) and emery paper are much used; but the loose powder applied as above although less cleanly, is in general somewhat quicker and also cheaper. For the plane surfaces and other parts of small-turned works required to be particularly flat, emery paper folded around a smooth file or

a flat piece of wood is used, or else flat pieces of mahogany, box-wood or metal, supplied with fine emery powder and oil are employed with still greater advantage.

In some few cases after the finest or flour emery has been used, fine crocus is similarly applied or with a buff stick, but this is unusual as two sizes of emery are alone generally employed. Some parts of superior works in iron and steel, especially the rounded edges, are brightened with the burnisher, but such parts require to be previously polished quite smooth; both the work and burnisher must be wiped thoroughly clean from emery or dust, the burnisher is then held against the work as it revolves, a little oil being interposed to lubricate the surfaces. *See* Burnisher.

4.—Screw Threads that are required to fit accurately and smoothly, and also to sustain frequent unscrewing, should be polished with a pointed stick and emery; very frequently the removal of the rough edges will make that screw enter which appeared to be too large, and the smooth screw present far less friction and disposition to wear out.

5.—The Heads of Screws are often finished with the side of an emery stick as they revolve in the lathe; and if they are to be burnished the emery must be carefully removed from the notch by folding the rag and drawing it through like a saw or the process will fail, and the burnisher will be injured.

6.—Small Round Rods used for inferior purposes and not requiring to be cylindrical, are often ground bright against the edges of large revolving grindstones driven by power. The rod is held rather loosely in the hands of the workman and at a small angle to the axis of the stone; then without any great attention on the part of the individual, the grindstone causes the rod slowly to rotate in his hands, so as to act on every part of its circumference, and the obliquity of the two axes also causes the rod to traverse endlong through the hands like a screw, and thus every part of the rod is acted upon successively by the grindstone.

7.—Cylindrical Works that require great accuracy are ground by methods that will be explained in Chap. VII., but other cylindrical rods of inferior kinds, used only as levers and for similar common purposes, are often polished between two sticks, (supplied with emery and oil,) placed transversely to the cylinder, grasped in both hands, and rubbed lengthways on the work as the lathe revolves. Considerable friction may thus be given on opposite sides, and therefore without bending the cylinder, the figure of which is materially improved by the treatment. Sometimes for greater purchase, the sticks are united at the one end by a loop of string or wire, and compressed at the other, like nut-crackers, with one or both hands.

8.—Lathes for Polishing.—In most manufactories it is usual to perform the polishing on common lathes kept entirely apart from those used for turning, machines which very generally take the form of a pedestal carrying a head-stock with a mandrel running in bearings, projecting each way with a polishing wheel at either end, with or without rests or supports for the work; so as to avoid the mischief that ensues when the emery or other gritty materials

find their way into the mandrels or other parts of the lathes used for turning. When it is unavoidable to use the same lathe for both purposes, careful workmen take scrupulous care to prevent the scattering of the powders, to so far diminish the risk; and in polishing spindles and pieces that require support at both ends it is good practice to employ another center for the popit head than that used for turning, this piece being especially liable to deterioration by the polishing powders.

FLAT WORKS.

9.—Large Sized Flat Works.—These are in almost every case castings in iron, wrought in the planing machine;—a machine that produces its results with so much accuracy and precision, that polishing is not frequently required as the concluding step. When however large planed works are polished, it is with rubbers of various kinds applied with emery and oil. Sometimes a flat lump of lead is cast upon the center of an old file, or of a still longer bar of iron; at other times a bar of wood serves as the handle, to which a piece of lead or wood, or wood covered with thick leather, is fixed by screws or nails; such rubbers are generally held in the two hands much after the manner of the spokeshave or drawknife, or they are worked by one very long handle as in smoothing a large slab of stone or marble. When the rubbers are large they are occasionally loaded with heavy weights, so that the workmen have only to drag them to and fro on the works, the forms of which latter are in general too diversified to offer much inducement to the application of machinery to rectilinear polishing.

10.—Medium Sized Flat Works.—Such of these as are of cast-iron are also for the most part worked in the planing machine, and if at all polished, it is done with emery rubbers nearly or precisely as above described; most of the flat parts of mechanism that are made in wrought iron and steel, are too irregular in their forms to admit of being worked otherwise than with the file. The black oxidized surfaces of forged works are often removed on the grindstone prior to the application of the file; this application of the grindstone is generally highly economical, it being comparatively much more rapid in its action and less costly in respect to wear and tear than the file.

The flat parts of iron works are sometimes reduced on the grindstone or on emery wheels to accurate plane surfaces, but this requires the assistance of mechanism; this subject, and the application of revolving metallic laps to the production of flat works, will be noticed in the practical chapters.

The coarser and larger of the filed works are sometimes left from the file, or without being subsequently polished; in which case the coarser marks left from the file when used in the customary manner, or from point to heel, are removed by the method known as *draw-filing*, in which the file is drawn sideways along the work; draw-filing is particularly employed in narrow pieces. Large broad surfaces are occasionally finished by giving a circulating motion to the file, thereby producing curly marks. Each of these latter processes are more effectual when the file is moderately supplied with oil, which lessens its disposition to become *pinny*, or clogged, by particles which stick into

it and scratch the work; but the reader is referred to the previous chapter on the File, Vol. II., page 852, for more detailed particulars of these applications of this useful instrument.

Works requiring a finish superior to that of draw-filing, are rubbed with an emery stick, or with rubbers of the various kinds already noticed, and supplied with emery and oil.

11.—SMALL SIZED FLAT WORKS, after having been draw-filed, are more usually finished with the emery stick, often followed by emery paper of different degrees of coarseness wrapped on a file or a square stick. The emery is moistened with oil for the more finished works, the dry rubber however gives the brighter surface, and it is sometimes applied with a curling motion so as to diversify the grain left on the work.

Buff sticks supplied with crocus are often used for the last gloss, but on small flat surfaces they must be cautiously applied for fear of rounding them, a defect that is easily distinguished, and very objectionable.

Still smaller works and those required to be very flat are finished with square slips of stone with oil, or slips of mahogany, brass or tin, any of which are used with fine flour emery or oilstone powder and then with crocus.

12.—SMALL FLAT WORKS OF HARDENED STEEL.—As it commonly happens that in the process of hardening steel works they are more or less distorted from their intended figures, and as in many cases it is impossible or inadmissible to restore them to the plane figure by the hack hammer, *see* Vol. I., p. 247, grinding is then resorted to, metal laps generally of lead with a little antimony, and laps of copper or of cast-iron are also employed with emery and water. When it is desired the works should present very true plane surfaces, the laps should be themselves very exact and flat. There is however a constant tendency to depreciate the figure of the lap, because the outer part or exterior diameter gets the more worn, on account of the greater rapidity of its action at that part. After the lap has been used, the mode of finishing described in the last article is also sometimes employed.

13.—WATCHWORKS IN STEEL.—Steel works of this diminutive kind are generally polished by the watchmakers, 1st with a steel rubber and oilstone powder, 2ndly, with a steel rubber and crocus of two degrees of coarseness, which is frequently called *red stuff* from its colour, and 3rdly with gun metal or glass rubbers supplied with fine crocus.

Some of the work is beautifully finished on tin or pewter revolving laps, into which the red stuff is embedded, occasionally with the burnisher, they are used nearly or quite dry, and when the laps are carefully preserved, they themselves present, under the magnifier, a beautiful smooth surface which they impart to the work.

Many of the grinders and rubbers for watchwork, are made from one to two inches square, and of steel, glass, gun-metal, tortoiseshell, horn, or ivory, &c., the small pieces are laid down upon the anointed grinders, and rubbed about with the fingers, as if the work were a muller used in grinding paint, this mode also preserves the flatness of the respective objects in a most admirable manner.

MALACHITE, or the massive green carbonate of copper, colour emerald green with

numerous lighter and darker green stripes and markings; the best specimens come from a mine in the Ural Mountains. The beauty or "figure" of this material is enhanced by its being traversed by numerous circular fissures, due to he imperfect joinings of the botryoidal masses of which it may be considered to be composed; but this also renders it difficult to work and polish, which processes require more than usual care and attention; it is nevertheless frequently wrought into works of considerable size, composed of many pieces fitted and cemented together or cut into thin slabs and used as veneers. The natural imperfections and faults in joints are filled with the different coloured malachite, finely powdered, and mixed with cement, very generally so as to defy detection. Notwithstanding its hardness it is considered by some lapidaries better to treat malachite like alabaster rather than as carnelian, but each method is followed.

MARBLE is polished in different modes jointly dependent on the nature of the marble, and the character of the work; some of the principal methods will be described here, and others in Chap. V.

Marble is generally worked by the lapidary after the manner of carnelian, sometimes of alabaster, but he is far less successful in this department of art than the sculptor and marble workers.

1.—MARBLE ORNAMENTS and small works intended for close inspection, which require the highest possible finish.—After the marble is sawn into slab the first operation is to grind it down with a flat coarse sand-stone and water, or with an iron plate, fed with fine sand and water, until all the marks of the saw are perfectly removed; 2ndly, a fine sandstone, (procured from Bilston,) is used with water, until the marks made by the first stone are removed; 3rdly, a finer sandstone which is found near Congleton, is applied to work out the marks of the former; 4thly, pumice-stone with water, and 5thly, snake stone is used, and the last finishes what is called the *grounding*.

Next comes the polishing, which is principally performed with rubbers of woollen cloth or list made to the size of about three inches diameter. As the 6th process a rubber is charged with flour emery and a moderate degree of moisture; this rubber is worked uniformly over every part, until the marble acquires a kind of greasy polish; 7thly, the work is completed with a similar roll of cloth charged with putty powder and water. Some prefer as the polisher, a piece of old cotton stocking not made into a rubber, and in some few of the more delicate works, crocus is used intermediately between the emery and the putty powder. It is necessary to wash the marble after each operation, so that not a particle of the previous polishing material may remain, otherwise the work will be scratched.

2.—MARBLE WORKS TURNED IN THE LATHE.—Turned works are polished as above, excepting that for the rolls of cloth are substituted two or three thicknesses of cloth supplied with emery or putty powder, and held upon the work by the hand, which is constantly moved about.

3.—STATUARY and large works in marble, which are dependent on their general design and effect rather than on elaborate finish, are executed by a different

class of artists, and require only part of the above processes to be resorted to. By Statuaries the marble is rubbed with two qualities of gritstone, the coarse, which is somewhat finer than Bilston, is known as *first grit*, and the fine as *second grit*. Thirdly, the work is smoothed with snakestone, after which the white or statuary marble is finished with putty powder and water, on a wooden *block* covered with thick *nap*, or felted cloth. *See* article RUBBER.

The Irish black marble is by some considered harder than the Derbyshire, and after the snakestone has been used, it is polished with tripoli on felt as above, and finished with putty powder or crocus, but the rubber is then covered with two or three thicknesses of stout linen.

The finest Welsh black marble is esteemed still harder and blacker than the Irish, and after the snakestone, is polished by laying a thin plate of copper or lead on the wooden rubber, and using therewith tripoli and water, and finally putty powder or crocus on linen as before. The Irish marble is less brittle than the Welsh, and better suited to carved ornaments. Marble is also sawn, ground, and polished by means of machinery, which will be described.

SCULPTURE.—The dull parts of sculpture are finished in four different manners, or rather, the complete process of smoothing is discontinued at various stages, so as to form four gradations, denoted by the respective paragraphs.

The marble is *First*, sometimes left from the long and very slender statuary's chisel, the reverse end of which is formed with a sharp circular edge or ridge, just like a hollow center, in order that the metal hammer which is of soft iron, tin, or zinç, may be slightly indented by the chisel, so as to avoid its glancing off; the chisel marks leave the surface somewhat rough and matted, intermediate between the granular and crystalline character.

Secondly, For surfaces somewhat smoother, rasps are used to remove the ridges left by the chisel, the rasps leave a striated or lined effect suitable for draperies, which is made more or less regular according to the uniformity of the strokes, or the reverse.

Thirdly, Files are employed for still smoother surfaces of the same character; and it is to be observed that the files and rasps are generally curved at the ends, to adapt them to the curvilinear forms of the sculpture. *See* the article on RIFFLERS, in the chapter on FILES, Vol. II., page 834.

Fourthly, For the smoothest of the dull or unpolished surfaces, the faint marks left by the file are rubbed out with Trent sand or silver sand and water, applied by means of a stick of deal cut to a point and rubbed all over the work in little irregular circles, as a child would scribble on a slate, and if the end of the stick is covered with two or three thicknesses of cloth, the marble receives a still rounder or softer effect than from the naked stick, for which the cabbage wood or partridge wood is sometimes used, the end of the stick is slightly bruised, so that the fibres of the wood may assume the character of the stiff brush, known by artists as a scrub.

The late Mr. Thomas Smith, a London sculptor, successfully copied the minute roughness or granulation of the skin, by a kind of etching which he was induced to try, thinking he could trace such a process to have been used in some of the most perfect of the ancient marbles that had not been exposed to

open air. The work having been smoothed with sand as above, he took a hard stubby brush, and therewith dotted the marble with muriatic acid, which quickly, yet partially, dissolves the surface. The stringency of the acid, which must not be excessive, is tested upon a piece of waste marble: the brush is hastily dipped in the acid, applied to the work, quickly rinsed in water, and then used for removing the acid from the marble. The process sometimes requires several repetitions occupying only a few minutes each time.

Fifthly, the bright parts of sculpture. These are exceptional, when required they have first to pass through the four stages already explained for producing the smooth but dull surface; after which, slender square pieces of the second gritstone and of snakestone are used with water as a pencil, and then fine emery and putty powder on sticks of wood; but the work is exceedingly tedious, and requires very great care, that the artistic character of the work, and any keen edges that may be required are not lost in the polishing. To avoid tediousness and the risk of deterioration, it is not unusual in carved black marbles and those of dark colours, after using the snakestone, to coat the work with varnish, by which a gloss is given without attrition. The pillars of the Temple Church, London, which are of Purbeck marble, were thus French polished, after the manner of furniture, when that building was restored.

MARBLES FOR CHILDREN.—These are principally manufactured in Germany; some are made of clay covered with a glaze and baked as in pottery; others are made of alabaster and marble; but the greater part are made of a hard stone found near Coburg in Saxony. The stone is first broken with the hammer into small cubical fragments, and about 100 to 150 of these are ground at one time in a mill, somewhat like a flour mill. The lower stone, which remains at rest, has several concentric circular grooves or furrows; the upper stone is of the same diameter as the lower, and is made to revolve by water or other power. Minute streams of water are directed into the furrows of the lower stone. The pressure of the runner on the little pieces rolls them over in all directions, and in about one quarter of an hour the whole of the rough fragments are reduced into nearly accurate spheres. Frequently a thick circular slab of oak or elm is used instead of the upper revolving stone. This simple process is the germ of the various machines, which will be described, that are employed for grinding the metal spheres used for anti-frictional bearings and other purposes.

MARQUETRY WORK.—This term, probably derived from the French definitions, *marqueterie en bris* and *marqueterie en métal*, see foot note, page 732, Vol. II., has been selected to denote a variety of works, also known as buhl work, reisner work, *parquetage*, mosaic, &c., in which two or more woods, metals, and other materials, are united by various modes of inlaying, some of which are entirely executed with the saw, as described in pages 731—739. The methods of polishing these works depend on the materials of which they are respectively composed, and are generally as follows.

2.—Marquetry entirely of Wood.—This is reduced to a level surface with the toothing plane, and is then scraped with the joiner's scraper, which so far as

possible is applied *obliquely* to the joints of the marquetry, as when the scraper is applied *parallel* with the joints, or broadside to them, it is liable to dig down, and if applied at right angles to the joints it does not cut so cleanly as in the inclined position, like the skew irons of some rebate planes. The scraper is sometimes employed with such good effect, that the work only requires to be rubbed with a few of its own shavings, as in many draftboards made of holly and ebony.

When the scraper is less successful, fine glass paper on a flat piece of cork is employed to smooth the work, and the paper is preferable if it is worn until it almost ceases to cut and has become uniformly choked or clogged with the fine dust from the work, but which latter must not be allowed to collect in hard partial lumps, a condition that may readily occur with resinous or greasy woods, as these lumps then scratch the work.

3.—Marquetry in Wood and Metal, and also those which contain ivory, pearl shell, tortoiseshell, and metals, require to be levelled very carefully with flat files handled after the manner of figs. 816 to 818, page 834, Vol. II., ending with a very smooth flat file, after which the scraper should be used if practicable, and followed by glass or emery paper employed very sparingly as above directed. When the metal preponderates emery paper is much to be preferred, and really good *sand* paper which is of an intermediate character between glass and emery paper has also been used, but as stated above, the paper of which kind soever should have but very little cut, should be applied dry, and allowed to become clogged, so as to act principally as a hard dry rubber or burnisher. If the polishing is at all in excess, the wood will inevitably be worn down so as to allow the metal or harder material to project above the general surface.

It is always particularly hazardous to resort to wet polishing with inlaid works, for if the water be carelessly used there is risk of its penetrating to the glue and loosening the pieces, and if the woods are only superficially wetted they are apt to curl up at the edges and become warped; and besides, the grain of the wood is almost certain to rise with the wet and leave a rough unsightly surface. Oil is preferable only so far as not dissolving the glue, but oil or water are alike inapplicable to light-coloured woods, which are almost sure to become stained by the polishing powders and the fluids used in their lubrication.

4.—Marquetry entirely of Metal, which is less common and more recent than the foregoing kinds, is first smoothed with a flat file, secondly it is very carefully scraped with a triangular or other scraper, thirdly it is rubbed with a stick of snakestone and water, fourthly with charcoal in the stick and oil, and it is finished with a coil of list or other rubber supplied with rottenstone and oil.

5.—Marquetry with Varnished Surfaces.—Many of the modern marquetry works, instead of having their surfaces polished simply by attrition as above described, are covered with varnish either applied with friction as in the so-called French polish, or the varnish is laid on in several coats with a brush and polished off with pumice-stone and rottenstone. Previously to their

being varnished, which processes will be hereafter described, the marquetry works are levelled with the file or scraper as the case may be, and smoothed with glass paper.

MEERSCHAUM.—A cream-white mineral earth composed of silica and magnesia, of light specific gravity, soft and homogeneous, found in veins from 30 to 40 feet below the surface of the hard serpentine rock, principally in Asia Minor, but lately, it is said, also in Mexico. It is imported in irregular convoluted nodules varying in size from about 3 to 12 inches in length.

After being soaked in water meerschaum is turned, filed and scraped into pipes as described Vol. IV. p. 570. The material is so soft as scarcely to admit of a true polish; the scratches are first removed and an even surface given by rubbing with fine or nearly worn out glass paper or with Dutch rush, it is then polished with Calsh, which see. A few pieces of the calsh are crushed with a pallet knife, slightly sprinkled with water and allowed to stand a few days to crumble into a fine powder which is fit for use. The meerschaum is twisted round and about, upon the flat face and rounded edge of a flannel covered buff wheel charged with the moistened calsh and revolving in the lathe, and the powder is also as plentifully rubbed on the work with a piece of flannel in the fingers. Subsequently the meerschaum is rubbed with a dry rag, then dipped in melted white wax, allowed to drain and dry, and finally lightly rubbed with clean flannel which completes the process.

MELTING in polishing,—a trade term for over-polishing by which sharp edges are seriously rounded or obliterated, damage which may arise from too long continuance of the friction, heating from over pressure on the wheels and other causes. The edges are said to be *melted* because their deterioration from the undue heat gives them the rounded character of arrisses in metal castings.

MILL, a general term used by lapidaries to represent their different wheels, as roughing-mill, cloth-mill, etc. *See* introductory article on WHEELS, also Chap. X. on Lapidary work.

MOSAICS consist of two varieties, the one has the design cut out in pieces of one stone or marble, or in various coloured stones when required for the differing colours in arabesques or in groups of leaves, flowers etc., as in Florentine mosaic, inlaid and cemented in corresponding recesses pierced partially or entirely through a slab or other piece of uniformly tinted marble, after which the whole surface is ground and polished level; some of these works are executed on a very small scale in more precious materials for jewellery. The methods followed in the production of *Marquetry* or similar work in wood are given page 737, Vol. II. The other variety or tesselated mosaic dates from antiquity and was practised by the Romans and far earlier by the ancient Egyptians, for pavements and mural decoration. Quasi-cubical pieces of various coloured stones of small size arranged in patterns with similar pieces all of one colour in the interstices were cemented down and rubbed level for

pavements, whilst in the mural works a great variety of materials, stone, glass, porcelain, etc., was employed to depict figures, drapery and accessories. The art appears never to have been lost; executed on the most minute scale it is well known in Roman jewellery, the surfaces of which are subsequently smoothed and polished by the lapidary like carnelian or agate, and in the colossal mosaics of St. Peter's, reproductions of Raphael's pictures in the Vatican, marvellous for delicacy, truth of colour and absolute facsimile, the work is executed literally in millions of morsels nearly if not quite as small as the above mentioned employed for jewellery. Among ourselves tesselated pavements are an ordinary industry, and are composed of small to larger pieces of differently coloured stone, or of earthenware moulded or cut to shape, put together like a child's puzzle bedded exactly level on a thin layer of sand on the concrete or other floor they cover, after which they are permanently held in position by thinly mixed parian cement flooded on the surface and well brushed in to fill all joints.

Mural mosaics, perhaps a higher branch of the art, are less common, those lately placed in the arches and spandrels of the choir of St. Paul's Cathedral, executed by Mr. Powell from the designs of Mr. W. B. Richmond, A.R.A., are entirely composed of tesseræ of gilt and opaque glass of all colours produced at the Whitefriars Glass Works, London. Small quantities of the glass are poured and rolled on iron plates into flat discs from one to three-eighths of an inch thick by about a foot in diameter, which are cut with the diamond into strips from one quarter to an inch wide, and the strips chopped across into irregular squares between two steel chisel edges worked by a hand fly-press. Formerly, as also now, the design copied and coloured on stout paper is cut into pieces which, laid on a table and coated with glue, are covered with the tesseræ arranged face downwards in their appropriate forms and colours; when dry the sheets of tesseræ are pressed side by side into the cement laid on the wall, the exposed surfaces of the little pieces therefore all at one level, and the paper washed off after the cement has set. A more modern method was adopted at St. Paul's; the brickwork or the stone previously roughened to give it a key was covered about half an inch thick with a cement composed of oxide of zinc, commonly called white zinc putty, mixed with powdered lime and a little wax and gold size, the two latter being added to keep the cement moderately soft for a few days, after which it dries hard and is more difficult to remove than the stone itself. A tracing of a portion of the design is placed against the smooth surface of the cement and the outlines marked through with a blunt steel point run along them. The artist-artisan provided with a pallette in the form of a tray divided into receptacles filled with tesseræ of all colours and with the design itself hung near him, proceeds to press each individual little piece of glass into the cement with his fingers, commencing with outlines and then filling in the broad shaded intervals; the pieces of glass are of all sizes, but should he require to fill in some particular gap he nips off the edges of a larger to the shape with a pair of the ordinary pliers, Fig. 906, Vol. II. The tesseræ are placed in fairly close juxtaposition, but no attempt is made to bring their surfaces to one level, the effect being

considered as richer when the reflected light is broken up by the faces of the individual morsels standing at all varieties of small angles to the general surface. On a very minute scale this process of packing in the pieces without subsequent levelling has been long used for one variety of Italian mosaic jewellery.

MOSLINGS.—The thin shreds or flakes of leather shaved off by the currier in dressing cow and calf skins, etc., are very generally used for cleansing small works and removing oil from metals that are being polished, for this they serve extremely well, being as bibulous as blotting-paper. The more carefully finished tapped holes, especially those from which the companion external screw is likely from time to time to be removed and replaced in use, when they have been completed with the plug tap, are cleansed from the oil and any loose particles of metal that may happen to remain in their threads, by means of a thin piece of moslings wrapped around a smaller, usually the taper tap, which is then passed through them.

COTTON WASTE, the refuse from the cotton mills, used in handfuls, is employed for similar cleansing purposes in all engineering workshops, and is a familiar object on the locomotive. This material is nevertheless often a danger to the workshop, for if the used oily cotton waste be thrown aside and remain unobserved in holes and corners, it is particularly liable to catch fire, if not indeed to spontaneous combustion, a fact of which the writer has had practical and unpleasing experience.

SPONGE CLOTHS which resemble a loose, coarse, soft canvas, are woven from cotton waste; these which may be used again and again after being cleansed by boiling in soda and water, are found by many to be more economical, whilst their regular collection for this purpose removes the above-named risk.

MOTHER OF PEARL.—*See* SHELLS.

NACREOUS SHELLS.—*Idem.*

NICKEL.—A bright yellowish white metal, never native, found in the ores of cobalt, copper, and numerous minerals in the forms of arsenides, sulphides, silicates, &c.; the principal sources of supply being Canada, Sweden, Germany, and the United States. The ores when roasted are treated chemically and metallurgically to reduce the contained nickel to its oxide and then the latter to the metallic form.

Nickel may be cast, and is malleable and ductile, but is at present little used pure except and largely for electroplating. It is universally employed in alloys from the *Packfong* or white copper of the Chinese to the German silver or electrum of Europe, for which *see* page 279, Vol. I.; also in the present British and bronze coinage of other nations in the proportions of 25 parts of nickel to 75 of copper, and it is curious that, according to Mr. Charleton, almost the same proportions of the metals are met with in Bactrian coins dated 235 B.C. An alloy of 20 parts nickel to 80 copper exhibits great tenacity,

and is employed at the Royal Arsenal, Woolwich, for casing the elongated lead bullets of military rifles. Steel alloyed with about 5 per cent. of nickel acquires a remarkable increase of toughness and tensile strength, and is said to be superior to all other for armour plates. Nickel and its alloys are worked and polished in the same manner as electrum.

NORWAY RAGSTONE.—*See* HONE SLATES, article 1.

OILS.—Vegetable, animal and mineral unctuous fluids, used for food, medicine, illuminants, lubrication of machinery and in varnish and other manufactures.

All the vegetable and animal oils have a base of glycerine combined with various substances and acids and are divided into two classes, viz., fixed or fatty oils and volatile or essential oils. According to Ure,—"the members of one class differ greatly and in nearly every respect from those of the other; the former are usually bland and mild to the taste, the latter hot and pungent. All the known fatty substances found in organic bodies whether of vegetable or animal origin are, according to their consistence, arranged under the chemical heads of oils, butters or tallows, and all possess the same ultimate constituents, viz., carbon, hydrogen and generally oxygen."

The mineral oils or hydrocarbons, used as illuminants, solvents, and alone or mixed with vegetable and animal oils as lubricants, are naphtha, petroleum, paraffine and benzole or benzine, all of which were formerly prepared by the partial or destructive distillation of bituminous substances such as coal, shale and many organic matters, but now from the crude fluid oil obtained in apparently limitless quantities from wells and natural springs in bituminous and oil shale deposits in North America, Canada, Scotland, Rangoon, Russia, etc.

The fatty oils all contain more or less acid, highly objectionable in lubrication; according to M. Chevreul, all contain either two or three of the constituents stearine, margarine and oleine, each of which bodies consists of glycerine combined with a fatty acid; boiled with alkalies they decompose into glycerine and the fatty acids, the former combines with the water and the residue with the alkali in the form of soap.—When first expressed, however, the vegetable oils usually show but little acid when tested with litmus paper; the best qualities in all cases are obtained when the seeds or pulps are subjected to the first and lightest pressure, subsequent heavier pressures, with or without heat, yield inferior qualities richer in acids; but in nearly all vegetable oils the acids develop and to an objectionable degree by atmospheric exposure, familiar in the example of olive salad oil which soon becomes rancid. The fatty oils also group into the drying and non-drying varieties of which the following kinds are most used.

Vegetable drying.—Linseed, Cotton seed and Nut oils.

Vegetable non-drying.—Olive, Colza or Rape, Sesame and Palm oils.

Animal non-drying.—Seal and Whale or train, Sperm and Neats-foot oils.

Films or small quantities of the drying oils on exposure to the air soon change by oxidation into a viscid, gummy condition and at last harden; used alone, these oils are entirely unsuitable as lubricants, but some proportion of

them is occasionally added in the compositions of lubricating greases for heavy machinery with the view of diminishing fluidity. On the other hand the drying property is invaluable in oils used with pigments and in the manufacture of varnish, printer's ink, &c., for which purposes it is increased by partially boiling down the oils with or without litharge, a plumbic oxide, which causes them to dry still more rapidly.

The non-drying oils are also liable to thicken and gum to a less extent, but seldom objectionably in lubrication, except in the bearings of machinery a long time out of use. In such case, if the oil has not become too hard and adhesive, it may be worked out by a plentiful supply of fresh oil when the machinery is again made ready for use; when absolutely caked the hardened oil may be removed by using liquid paraffine, with the bearings temporarily slackened, instead of oil as a solvent; but in the more delicate machinery it is better practice to take the parts asunder and to clean off the dried oil by rubbing with a rag with fresh oil or paraffine; benzine is a more active solvent, but it should be used away from a light on account of its explosive vapour. The vegetable oils used as lubricants frequently corrode surfaces and bearings by the acids they contain, sometimes to a deleterious extent; their use should be avoided whenever possible, and *absolutely* for the bearings of lathe mandrels and all parts of apparatus for ornamental turning and similar accurate machinery, for which animal oil should alone be used.

The non-drying oils withstand considerable changes of temperature without sensible deterioration of their lubricating qualities, with cold they tend to thicken, with heat they become more fluid, but beyond certain degrees of heat they decompose and vapourize. They also continually work out and escape from between spindles and bearings which, unless re-supplied with oil, then dry, heat and damage one another, and in such as exactly fit, as mentioned with respect to the hardened steel mandrels and collars of lathe heads, p. 96, Vol. IV., will sometimes even blister and mutually destroy their surfaces, the oil used in lubrication, therefore, has to be constantly renewed, and the bearings of shafting and in larger machinery usually carry a supply in some form of oil receptacle attached to them; for the better class lathes a tubular oil can with a cover and dipper is often fixed to the lathe head to supply the mandrel. In early times the tip end of a horn was hung on to one of the popit heads for oiling their center points,—"with its Tip downwards to hold Oyl in, and ought to have a Wooden round *Cover* to fit into it, that neither Chips nor Dirt get in to spoil the Oyl."—Moxon, 1703, p. 171.

1.—The preparation of oils differs for those obtained from vegetable and animal substances, but to no great extent for individuals of either variety.

LINSEED OIL (*Linum usitatissimum*).—The seed first bruised between rollers, adjustable in their approach to the size of the seed to be crushed, is then ground into meal in iron flat-bottomed pans under granite edge runners; and the meal is placed in woven horse-hair or coarse sacking bags, partially filled, or in cloths of the same materials thickened and corrugated with pieces of rope at the centre, the sides or flaps folded over the meal. These or the

bags, with stout corrugated iron plates interposed, are piled one on another and subjected to pressure in an hydraulic press, the force controlled by a safety valve so as not to exceed a definite amount; and the oil expressed escapes through the bags and is collected below. Linseed contains about 35 per cent. of oil; some 25 per cent. is obtained by the above cold pressure, which best quality is of a bright golden colour and not disagreeable in taste nor scent. The oil cakes withdrawn from the bags are then broken up, reground and heated in steam jacketed pans to about 170° Fahr.; the meal, also sometimes saturated with steam admitted to it, is continually moved by a revolving stirrer to prevent its charring, and pressed whilst hot it yields a second quality of oil of darker colour and acrid taste.

Absolute exhaustion by expression does not result from the greatest possible pressure, and about 10 per cent. of oil always remains in the oil cake; for this reason extraction by solvents, bisulphide of carbon, the volatile petroleum ethers, canadol, &c., is also employed. The apparatus consists of a row of hermetically closed metal cylinders connected one to the other by pipes above and below, which contain the meal ground as before, but dried; the liquid bisulphide of carbon enters by gravity at the one end, circulates through the series of cylinders and passes saturated with oil into a vacuum chamber at the other. The solution is then heated in a steam jacketed retort to 114° Fahr., the boiling point of the bisulphide, which passes over and is condensed for re-use; after which, steam forced into the resulting oil in the retort and vapourized by boiling carries off all remains of the solvent. The oil is subsequently thoroughly stirred with 2 per cent. of chloride of zinc to free it of the colouring matters extracted from the meal. Pure bisulphide of carbon also dissolves caoutchouc, gutta percha and wax.

Linseed oil boils at about 260° Fahr.; that prepared for varnishes is kept boiling at nearly twice this heat until it loses about one-twelfth of its weight, when it is sufficiently increased in drying quality; in the manufacture of printer's ink it is boiled until reduced by one-sixth of its weight. More considerably reduced by boiling down it changes into an elastic, gummy substance very like caoutchouc, which is used for tubes, probes and other surgical appliances. The oil is continuously boiled for about thirty-six hours to effect this reduction, and then for five or six hours longer in nitric acid diluted with water; the resulting plastic material whilst still warm may be drawn or moulded into any shape, it hardens when cold, and resoftens when warmed through in hot water.—Heated to about 700° Fahr., linseed oil takes light and burns away to a brown resin-like residue; it is treated in this manner, with the burning arrested after a short time, to obtain the sticky substance known as birdlime. Linseed oil is much adulterated with colza, a non-drying, and with other oils.

Cotton Seed Oil (*Glossypium herbaceum*) is prepared by cold and hot pressure in the same manner as linseed. The crude oil is dense, about thirty-five times less fluid than water, of a dark yellow colour, and deposits a thick sediment. It is refined by agitation with caustic alkali, which is afterwards removed by *washing* with water; after a period of repose to allow the

impurities and alkali to settle, the thinner, cleansed and paler oil is drawn off from the surface of the water; several repetitions of this process result in finer and straw-coloured oils. Cotton seed oil consists principally of palmitin and oleine, and is between the drying and non-drying oils in quality; it is used for making soap, with paint, for lubrication and extensively for the adulteration of olive oil for the table; for this last purpose the palmitin is separated from it to lower the specific gravity, but it should be said that large quantities of the more highly refined cotton seed oil are now used, on its own merits, as a substitute for olive oil in cookery.

NUT OIL.—The best is expressed from the kernels of the common walnut. The nuts gathered in the autumn are not pressed until the winter, when the oil is found to clarify better; the shells and skins are removed and the kernels bruised in mortars and pressed in small hand-presses. Cold expression yields about 35 per cent. of the weight in virgin oil, or hot pressure sometimes as much as 50 per cent., but of a second quality. Walnut oil is colourless and has higher drying properties than any other oil, but it easily becomes rancid; it is used as a vehicle with and in the preparation of artists' colours, and in the manufacture of a fine quality of white varnish. It is adulterated with bleached linseed oil, but this may be detected on boiling a small quantity in a test tube, by the separation of the linseed in a flocculent brown deposit.

OLIVE OIL, expressed from the fruit of the *Olea europæa;* the seeds, skin, stones and pulp all contain oils of different constituents. For the choicest olive oil the picked fruit has the skin and stones removed by hand, the flesh is bruised in mortars and the pulp is placed in linen bags which are twisted to express it; after settling the oil is filtered. For best or virgin oil the ripe fruit after undergoing a slight fermentation spread out in layers for some days in dry cellars, is crushed between rollers or under edge runners, without breaking the stones; the results enclosed in matting bags placed one on another are subjected to gentle pressure and the cold drawn oil runs from the base of the press into casks partially filled with water. A second quality of oil is drawn by increased pressure and received in separate casks. The contents of the bags are then broken up, boiled with about their weight of water and pressed whilst hot for a third quality, the mixed oil received in cisterns. The oils stand several weeks to fine on the water before they are drawn off into bottles and casks for export.

COLZA OR RAPE OIL (*Brassica campestris*).—This oil expressed from the seeds after the same manner as linseed oil is mainly employed as an illuminant, but also largely in the adulteration of linseed, olive and others. It is light in colour and has an acrid, pungent taste which is neutralised by boiling the oil with 3 or 4 per cent. of starch; the oil after settling to deposit is further freed of the starch by filtration.

Many of the fat oils are filtered in the course of their purification. Woollen and felt conical bags and perforated wood and metal cases, the holes plugged with cotton or wool, are employed for moderate quantities, but require frequent cleansing and renewal. The filters for considerable quantities

are made in the form of tall metal cylinders open at both ends and crossed by iron bars at the base; a perforated loose wooden bottom rests on the bars and is covered above in layers—(i.) a thickness of coarse linen canvas, (ii.) a sheet of linen, (iii.) a layer of tow, (iv.) a thick layer of moss, (v.) a sheet of linen, (vi.) a similar perforated wood plate to that at the bottom; this is surmounted by a second series of layers in like order to the first and sometimes by a third. Every series is moderately compacted by pressure before adding the next, they serve for about three weeks and are then renewed.

Sesame or Cameline Oil is obtained from the seeds of *Myagrum sativum* and *M. dentatum*, principally grown in Asia. The imported seeds are expressed like linseed; cold pressure yields about 20 per cent. and hot 30 per cent. of their weight in oil. Sesame oil is exceptionally free from drying properties, which it does not acquire by any treatment; it is used in the making of soap, mixed with lubricating oils, and after purification and age, to sophisticate olive oil. *Palm oil* is extracted from the vascular pulp of the nuts or fruit of the *Elæis guineensis* and of the African oil palm, *E. melanococca*; the best is obtained by expression from the comminuted fresh nuts, or by boiling them in water; for the ordinary oil the fruit is allowed to rot, broken up into pulp and pressed in bags made of the fibres of the palm leaves; purified by boiling with water and deposition. Very dark when fresh, palm oil soon becomes lighter in colour, it congeals at a temperature of 80° Fahr. and then much resembles butter; it consists of palmitin, oleine and large quantities of free acids, hence it is always rancid. It is used in the manufacture of illuminants and lubricating greases.

Purification of Vegetable Oils.—When allowed to stand a sufficient time to clarify, all of these oils deposit the major part of their albuminous and mucilaginous matters, which contain the colouring substances and most of the acids, after which the purer upper oil is drawn off. Commercially this long process has to be hastened and the most general practice is as follows—(i.) One to one and a half per cent. of sulphuric acid is added to the oil heated to 80° to 90° Fahr., and the two are thoroughly mixed by agitation in covered pans by revolving or churn-like stirrers; power and small hand machines are both used; the acid is gradually added and after one or two hours of agitation carbonizes and destroys the albumen, &c.; the oil then stands from one to two days to allow the dark brown flocculent results to deposit. (ii.) The clearer upper oil is drawn off into a second similar pan and vigorously washed by prolonged agitation with boiling water, to free it of adhering sulphuric acid. (iii.) The oil and water run off from the washer are received in clarifying cisterns in which they remain until they entirely separate; the oil is then sometimes washed a second time. (iv.) Some of the oils are finally filtered.

The seed oils in some cases are purified by incomplete saponification, which process is briefly as follows:—they are heated and mixed by stirring with from 2 to 3 per cent. of caustic soda. The alkali renders insoluble, and the lather formed envelops and collects the matters to be expelled which

deposit with it when the oil is allowed repose; the supernatant oil is drawn off and filtered; the deposits are used in soft soap, &c.

2.—Whale, Seal, Walrus or Train Oils, obtained from the fat of several varieties of these animals; the process for the reduction to oil is virtually the same for all. The largest animals when despatched are secured alongside the ships by tackle with which they may be turned about, and the men standing upon them rip off long parallel strips of the blubber which encases the body under the skin. These hacked into pieces and cleared of flesh and skin are cut into slices with a two-handled knife or in a machine, and heated in cauldrons, from which the oil is transferred to a cooling tank from whence the barrels are filled. In the factories at the ports the blubber, with the flesh and skin loosened by their partial decomposition whilst stored on board ship, cleaned by scraping, is heated in circular vats with perforated bottoms through which the oil escapes into lead-lined cisterns sunk in the earth below, some of which are capable of holding 25,000 lbs. of oil. A second quality is obtained by pressing the heated residue from the vats. After boiling in steam pans the oil runs through pipes into settling vats from which it is barrelled for transport. Train oil is dark in colour and nauseous to taste and scent; it is purified and partially freed of its acids by subsequent boiling with acetate of lead and with tannin to eliminate the glycerine; its adulteration is not profitable.

Sperm Oil, superior in every particular to any other fish oil, is taken from several varieties of the *Physeter macrocephalus* or Cachelot whale, a species which inhabits warmer latitudes, and is, therefore, less provided with oil. The oil is found in the tissues and also collected in a large cavity, called *the case*, on the right side of the head and snout, which is filled with it both fluid and combined with spermaceti. To separate the latter the lumps are melted and poured into thick flannel filters in which the spermaceti congeals and the oil passes through. This valuable oil is non-drying, very fluid and comparatively free from acids, it is preferred for the lubrication of the spindles of cotton mills; unfortunately the supply is limited, hence it suffers from adulteration with mineral, shark and other fish oils.

Lard and Tallow Oils used in a few processes in polishing, principally with the metals, are obtained by submitting the respective animal fats, first cleaned and rendered down by heat and when again cold, to considerable mechanical pressure. These oils are generally used for the above purposes in the condition in which they run from the press; but they are highly charged with the fatty acids, which may be more or less removed by saponification.

Neats-foot Oil is obtained from the first boiling of the feet of oxen from which the skin and hoofs have been removed; the scum taken from the surface of the water consists of animal matter and impurities, clots of fat, and oil, which last is separated by filtration. The oil is then stored in tall vessels to settle and deposits its thicker matter and the accidental or still adhering water, from which sediment the thinner oil is drawn off for use. Neats-foot oil is of the colour and consistence of very thin gruel with some flocculent matter, it has but little acids which can be removed without difficulty, it never becomes rancid,

does not readily freeze nor get dry by heat, and when pure is in all respects the best lubricating oil; it is also the best for use on the oilstone.

The oils of commerce are rarely pure, most are not infrequently adulterated with other varieties of inferior value which also differ in their properties; sperm and neats-foot oil, perhaps, can least be depended upon for purity. Oils readily mix mechanically and many chemically, that employed for the sophistication is selected of nearly the same specific gravity as that of the oil to which it is added, hence the pure and mixed show little or no difference in colour or otherwise except in their behaviour when in use. Complete analysis is desirable for detection: but there are numerous tests, the re-agents for most of which are given by Braunt, which detect the presence of other oils and usually suffice for commercial purposes.

The difficulty of obtaining an oil trustworthy as to purity and possessing the qualities necessary for the lubrication of delicate machinery, led the writer to experiments in the preparation and use of several of the vegetable, animal and fish oils. The result, in his view, is the absolute exclusion of all vegetable oils, all of which from their native acids and the remains of those added in their purification, are liable to corrode and should not be used alone nor mixed with other oils. The fish and animal oils, generally, have less acids, of the former, sperm oil, when treated much after the manner described below for neats-foot oil, comes next to it in value. Pure neats-foot oil, however, proves incomparably the best in all particulars; it is prepared by the writer's firm as follows:—

3.—Anti-corrosive or pure Neats-foot Oil.—The preparation is commenced with the fatty scum and oil obtained by the boiling of the animal matter, four gallons of which are treated at one time. (i.) This quantity is poured into a long conical filter made of the thickest printer's blanket, and contained in a tall metal cylinder which has a tap at the base and another a little way above it. The oil takes some time to run through and settle in the cylinder, from which its clearer portion is drawn off by the upper tap and the residue is returned to the filter when that has been scraped out and receives a fresh charge. The oil first drawn off is passed through a second similar filter from which, after a period for settling, the clearer portion is transferred to white glass quart wine bottles, each of which contains a strip of clean sheet lead. (ii.) The oil thinner by the filtering is opaque and turbid, and the filled and corked bottles are arranged on shelves in windows exposed to the full light, where they remain undisturbed for about twelve months to deposit, and during this period each bottle is once or twice removed, unshaken, and subjected for some days to a temperature of about 20° Fahr., a cold which does not affect the oil but freezes the particles of mucilage and animal matter still present, which then become flocculent and very slowly deposit. The oil has then separated into two portions, the upper two thirds very much clearer than that containing the deposit below. A second set of bottles are then filled with these clear portions only, carefully decanted into them from the first, and the contents are subjected to the same treatment and exposure as the first, resulting in a smaller and less dense deposit and a still clearer supernatant oil. (iii.) The transfer to fresh sets

of bottles, the same exposure to light and freezing, but omitting the strips of lead, is repeated a third, a fourth and if necessary a fifth time, the oil throughout very slowly thinning, clearing and bleaching until at last it refuses to deposit and is limpid as water and fit for use. The long exposure to light besides bleaching the oil, appears to have a chemical effect in destroying the native acids, and to obtain a thorough transfusion of the light the oil is exposed in such small quantities. The process is tedious, and the original charge of four gallons yields only about one and a half pints of the refined oil, but it is repaid in the results; this natural preparation used for lubrication performs three or four times the work of ordinary refined oil, it is absolutely anti-corrosive, for these reasons and from its invariability under extreme changes of temperature it is used by watch and clock makers; thinly applied on bright steel or iron it secures immunity from rust.

4.—Railway Greases, semi-fluid, butter-like lubricants composed of fats, oils, etc. Braunt mentions the following as approved proportions and compounds:—

1. Refined tallow 100, Olive oil 10 to 20, Lard 10 to 13 parts.
2. ,, ,, 100, Train oil 50 to 75 parts.
3. ,, ,, 100, ,, 100. Powdered sulphur 50 parts.

The fats are melted in a water bath provided with apparatus for stirring, the oils and then the sulphur are gradually added. The heat is then sometimes withdrawn and the stirring continued until the mixture congeals.

4. Refined tallow 60, Palm oil 120, Soda 10, Water 80 parts; for summer.
,, ,, 80, ,, 200, ,, 15, ,, 10 parts; for winter.

Used in England; the tallow is heated to 300° Fahr., the oil added and the soda dissolved in the water, both gradually in small quantities, stirred throughout and after the heat is cut off until the mass is nearly cold.

5. Refined tallow 260, Train oil 230, Soda 23, Water 500; used in France.
6. ,, ,, 260, Colza oil 55, ,, 20, ,, 340; for summer.
,, ,, 230, ,, 85, ,, 20, ,, 350; spring and fall.
,, ,, 180, ,, 120, ,, 20, ,, 360; for winter.

Used in America:

7. Paraffine oil 10, Colza oil 90 parts; recommended, not much used.
8. Rosin oil 100, Train oil 50 parts; *see* Resin.

The fats restrain the fluidity of the oils which augments with the heat caused by the friction, without them the oils work out; and a greater proportion of these more solid constituents are generally employed in summer than in winter. The soda and water form emulsions with the fats and oils, which serve to neutralize the acids and to combine a considerable quantity of water, to increase the bulk and reduce the cost of the compound without detriment to its lubricating properties.

OILSTONES.—1. Turkey Oilstone cannot be considered as a hone slate, having nothing of a lamellar or schistose character, but is usually of a close, compact and fairly homogeneous nature. It is usually considered to be found in the interior of Asia Minor and it is shipped from Smyrna, but Mr. F. Partridge,

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the principal importer at that port, says,—"it is probable that the stone exists in many parts of Asia Minor and in the Islands of the Greek Archipelago, but all which is shipped from Smyrna is quarried in the Island of Crete and is brought here for sale in rough irregular pieces in small coasting vessels; the quarries are owned and worked by Turks."—There are three qualities of Turkey stone, a dark blue to black variety and a lighter blue grey stone, both of which go to London, the latter being the less hard is the more easily cut into shape; the third quality is much softer, almost white in colour and easy to work, but it is very brittle and consequently more difficult to get in large and even pieces; this quality of stone is shipped principally to France.

Mr. J. J. H. Teall of the Royal School of Mines, who has been good enough to analyze the stone for these pages, says—"It is an aggregate of excessively minute crystalline particles of silica in which rhombs and grains of calcite are embedded. When the calcite, which does not form any large proportion of the rock, is removed, the residue contains 98 per cent. of silica. There is therefore no doubt that the cutting is effected by silica probably in the condition of quartz. The rock is allied to chert, but it owes its peculiar properties to the readiness with which it breaks up into a uniform and extremely fine grained silicious powder."

Turkey oilstone can hardly be surpassed as a whetstone in its property of abrading the hardest steel, in the quality of the edge it produces on cutting tools, or in the rapidity of its action. The friable nature of the stone pointed out by Mr. Teall, exactly explains the practical experience that the best cutting edge is most quickly attained on those specimens of Turkey stone which appear to wear away almost or as quickly as the edge of the tool sharpened upon them. The softest stones sharpen or *cut* the quickest, but their surfaces require frequent reinstatement; the dark blue and hardest fairly resist the pressure in sharpening gravers and the smaller pointed tools without rapidly wearing into holes or furrows. The flat surface of the oilstone is kept in condition by, so far as possible, evenly distributing the wear upon it; this is successfully attained on those used for plane irons and wide chisels by employing a stone of rather less width than that of the tool; the plane iron is traversed along the stone both reciprocally and slightly diagonally simultaneously, hence the whole width of the stone is throughout always entirely covered by that of the iron being sharpened upon it. Turkey stones are refaced by grinding them on a flat iron plate fed with dry emery powder.

2.—Arkansas Oilstone, Novaculite, or nearly pure quartz, is found in moderate quantities in the one American State only from which it takes its name. The best quality which is rare, is pure milk white, with no perceptible grain, equally hard throughout, absolutely homogeneous, and has a conchoidal fracture. Arkansas stone does not wear appreciably under the most vigorous usage with pointed or wide edged tools, it cuts far more slowly than Turkey stone but its perfection and permanence of surface produces a keen and more uniformly perfect cutting edge, it is in every respect an admirable oilstone. A second quality from the same quarries appears slightly crystalline, is generally "off colour" and is sensibly less smooth when tested by the thumb nail drawn along

it; this is said to be cut from the mass closely surrounding a nucleus of the best and true Arkansas oilstone. WASHITA and some other comparatively coarse grained varieties are sometimes mistaken for inferior Arkansas oilstone, but are greatly inferior to it in all respects. Turkey and Arkansas oilstone are both used with oil.

Mr. James D. Dana says,—"Novaculitic-quartzyte or Novaculite is only in part an extremely fine grained silicious rock. Of this nature is the variety from Whetstone or Hotspring Ridge in Arkansas. This ridge 250 feet in height above the Hot Spring Valley is made up of the beautiful rock, 'equal' says D. D. Owen, 'in whiteness, closeness of texture, and subdued waxy lustre to the most compact forms of the whitest varieties of Carrara marble. Yet it belongs to the age of the millstone grit." Dr. Owen supposes it to have received its impalpable fineness through the action of the hot waters on sandstone. An analysis of the rock gave him (Second Rep. Geol. Arkansas, 1860, page 24) Silica 98·0, Alumina 0·8, Potash 0·6, Soda 0·5, and traces of lime, magnesia and fluorine 0·1=100". Manual of Mineralogy and Lithology, London, 1879.

3.—OILSTONES FITTED IN CASES.—The rough irregular pieces of either of these oilstones scarcely ever exceed about 3 inches square and 10 inches long, and are generally about one third smaller; they are cut into rectangular forms with the lapidary's slitting mill and diamond powder, the blocks are then rubbed smooth with sand or emery on an iron plate. The piece of oilstone is generally inlaid in a block of wood, in which it is cemented with the putty used by glaziers, and to avoid the deposition of dust a wooden lid is usually added; the lid is sometimes covered with a thick piece of buff leather which serves to absorb the oil from the tool and is used in the manner of a razor strop. The oil employed on the oilstone should be indisposed to dry or thicken, in this respect neats-foot oil is the best, but sperm oil is nearly as good. The used and blackened oil should also be cleaned off from the stone from time to time.

The joiner often puts three or more small points in the stock or bed of the stone, that it may take a firm hold of the work bench when dabbed down thereupon; and the turner adds two fillets so that it may fit transversely on the bearers of the lathe.

4.—OILSTONE SLIPS, are small pieces of the above stones cut into different forms and sections by the lapidary. Some oilstone slips are fairly parallel, flat pieces from 3 to 6 inches long, others thin and thick have rounded edges and are cut of wedge like section, that the semicircular edges of one slip may be of two sizes and curvatures for sharpening gouges, moulding plane irons and other concave edged tools.

Arkansas pencils are smaller pieces from 3 to 5 inches long, of square rhombic, knife edge and other sections, ranging from $\frac{1}{8}$ to $\frac{1}{2}$ inch in thickness. The square and rhombic forms are particularly useful for sharpening the internal right angles in the delicate step drills and other tools used in ornamental turning, and with the latter each half of such a cutting edge can be operated upon without touching the other. Oilstone slips $\frac{1}{4}$ to $\frac{3}{8}$ inch square

are used for polishing metals, after the manner of files, by mechanicians, watchmakers and others.

5.—Oilstone Powder.—Fragments of Turkey oilstone when pulverised sifted and washed, are much in request by mechanicians. This abrasive is generally preferred for grinding together those fittings of mathematical instruments and machinery, which are made wholly or in part of brass or gun metal; for oilstone being softer and more pulverulent than emery, is less liable to become embedded in the metal, which latter is then apt continually to grind and ultimately damage the accuracy of the fittings of brass works. In modern practice it is usual, however, as far as possible to discard the grinding together of surfaces, with the view of producing accuracy of form or precision of contact.

Oilstone powder is preferred to pumice-stone powder for polishing superior brass works, and it is also used by the watchmaker on rubbers of pewter in polishing steel.

ONYX, a variety of Chalcedony that is wrought by the lapidary like Carnelian.

OPAL.—This beautiful iridescent gem although soft, is very brittle and tender on account of the numerous fissures by which it is traversed, and that apparently give rise to the splendid play of colours seen in precious opals of fine quality. Opals are always cut with rounded faces, and are more generally treated like alabaster than carnelian.

OXIDES OF IRON.—The red and black oxides of iron, and mixtures of them, are prepared by manufacturing chemists at Liverpool, Sheffield, Derby and elsewhere, as polishing powders, commercially known as crocus, rouge, red stuff, colcothar of vitriol, &c., and the same substances are also employed as pigments, under the name of red-brown, purple-brown, &c. The ordinary manufacture of crocus will be first noticed, and then the more exact method, required in the higher branches of scientific art in order completely to avoid the accidental admixtures of silex and other impurities. As however these several matters have been elsewhere described with great exactness, it is conceived best to quote these passages, and it is to be observed that articles 1, 4, 6 and 7 are literal extracts from Mr. Thomas Gill's paper on the preparation of the metallic oxides, contained in Tech. Repos. vol. 1, pages 431-5.

1.—Crocus and Rouge.—"These are manufactured at Liverpool by persons who make it their sole occupation, in the following manner. They take crystals of sulphate of iron, (green vitriol or copperas,) immediately from the crystallising vessels, in the copperas works there, so as to have them as clean as possible; and instantly put them into crucibles or cast iron pots, and expose them to heat, without suffering the smallest particles of dust to get in, which would have a tendency to scratch the articles to be polished. Those portions which are least calcined, and are of a scarlet colour, are fit to make rouge for polishing gold or silver; whilst those which are more calcined, or have become red, purple, or bluish purple, form crocus fit for polishing brass or steel. Of

these, the bluish-purple coloured part are the hardest, and are found nearest to the bottom of the vessels, and consequently have been exposed to the greatest degree of heat.

2.—Mr. Andrew Ross's Mode of Preparing Oxides of Iron.—"Dissolve crystals of sulphate of iron in water; filter the solution, to separate some particles of silex which are generally present and sometimes are abundant; then precipitate from this filtered solution the protoxide of iron by the addition of a saturated solution of soda, which must also be filtered. This gray oxide is to be repeatedly washed and then dried: put it in this state into a crucible, and very gradually raise it to a dull red heat; then pour it into a clean metal or earthen dish, and while cooling it will absorb oxygen from the atmosphere, and acquire a beautiful dark-red colour. In this state it is fit for polishing the softer metals, as silver and gold, but will scarcely make any impression on hardened steel or glass. For these latter purposes, I discovered that it is the black oxide that effected the polish, (and this gives to the red oxide a purple hue, which is used as the criterion of its cutting quality in ordinary,) therefore, for polishing the harder materials, the oxide must be heated to a bright red, and kept in that state until a sufficient quantity of it is converted into black oxide to give the mass a deep purple hue when exposed to the atmosphere. I have converted the whole into black oxide; but this is liable to scratch, and does not work so pleasantly as when mixed with the softer material. The powder must now be levigated with a soft wrought iron spatula, upon a soft iron slab, and afterwards washed in a very weak solution of gum-arabic as recommended by Dr. Green in his paper on Specula. The oxide prepared in this manner is almost impalpable, and free from all extraneous matter, and has the requisite quality in an eminent degree for polishing steel, glass, the softer gems, &c." *See* Emery, article 4.

3.—Lord Rosse's Mode of Preparing the Peroxide of Iron.—"I prepare the peroxide of iron by precipitation with water of ammonia from a pure dilute solution of sulphate of iron; the precipitate is washed, pressed in a screw press till nearly dry, and exposed to a heat which in the dark appears a dull low red. The only points of importance are, that the sulphate of iron should be pure, that the water of ammonia should be decidedly in excess, and that the heat should not exceed that I have described. The colour will be a bright crimson inclining to yellow. I have tried both potash and soda pure instead of water of ammonia, but after washing with some degree of care, a trace of the alkali still remained, and the peroxide was of an ochrey colour till overheated, and did not polish properly."

4.—Jewellers' Rouge.—"Is prepared by persons in this metropolis, by decomposing sulphate of iron with potash; well washing the yellow oxide of iron, to free it from the sulphate of potash; and slightly calcining it, till it acquires a scarlet colour."

5.—Specular Iron Ore when finely pulverised and washed, makes a polishing powder which is recommended for razor strops and other uses. It closely resembles both in appearance and effect the crocus artificially prepared from the sulphate of iron.

6.—ARTIFICIAL SPECULAR IRON ORE.—"This is made in the following manner. Equal parts of sulphate of iron and hydrochlorate of soda, (common salt,) are to be well mixed by rubbing them together in a mortar; the mixture is then to be put into a shallow cupel or crucible and exposed to a red-heat: a considerable quantity of vapour will be disengaged, and the matter will run into fusion. When vapours no longer arise, remove the vessel, and let it cool.

"The mass will be of a violet-brown colour, covered with extremely brilliant scales resembling mica, and perfectly like the specular iron-ore. This mass must be dissolved in water; as well to separate the sulphate of soda which is formed by the decomposition of the two salts employed, as to wash over the lighter particles of uncrystallized oxide, which forms an excellent polishing powder. The fire must not be continued too long, nor be too violent; for then the powder would become black, extremely hard, and produce no good effect. The artificial specular iron-ore is the more preferred, the nearer it approximates to the violet colour. The micaceous scales which subside after the washing over of the powdery part, afford an excellent material for razor strops, when applied to the strop with a little grease previously rubbed over it."

It has been suggested to the author by an experienced chemist, that the atomic proportions of the sulphate of iron and common salt, should be taken for the last process, and when it is considered that, as noticed by the Earl of Rosse, the limit of perfection in the polishing of specula depends mainly on the fineness and efficiency of the polishing material, it becomes evident that the subject demands every care in its investigation, which may apologize for the length of the foregoing articles.

7.—AN IMPROVED TRIPOLI, FOR POLISHING GOLD AND SILVER.—"The basis of this excellent Tripoli consists of a mineral substance, abundantly found in the coal and iron mines of Staffordshire, &c. &c.; known by the name of *clunch*, or *curl stone*. It had formerly been employed for no other purpose than as a material for mending the roads. It is a compound of *iron*, alumina, lime and silex."—Mr. Gill proposed this application of *clunch* from the external and chemical resemblance it bears to *Septaria*—the well-known basis of the Roman Cement, the employment of which in polishing he had previously advocated. He says: "The polishing effects of the calcined and pulverized *clunch* are however still superior to that of the *Septaria*, when prepared in a similar manner; and are, indeed, in point of quickness of action in producing the polish, and in the beautiful black lustre which it gives to the gold or silver, far beyond anything I have ever met with."

OXIDES OF LEAD AND TIN.—*See* PUTTY POWDER.

OXYGEN, compressed to about 120 atmospheres and supplied in portable steel cylinders of from 3 to about 200 feet capacity, has lately come into extensive use for the blowpipe, for brazing and for general metallurgical work in which intense local temperatures and pure flame are desiderata; it is also employed in this form for the oxy-hydrogen lime light, in chemistry, and for medical inhalation.

The present large commercial production by the barium process results from the researches of M. Boussingault, a distinguished French chemist, who

discovered that barium mon-oxide at a dull red heat seized upon the oxygen of a current of air directed upon it and was converted into per-oxide, and that this latter when raised to a higher temperature gave up the oxygen it had absorbed and was reconverted, practically without loss, into the mon-oxide. This curious property for many years remained unproductive until Mr. Brin, by a special method of preparing the mon-oxide, by thoroughly purifying the air used for per-oxidation, and by conducting that operation under pressure and the de-oxidizing the barium in a partial vacuum, overcame the earlier difficulties, among them the injuriously high temperatures previously required, and established the commercial production of compressed oxygen gas now worked by Brin's Oxygen Co. in London, and by several other companies working under their licence. The plant consists of a series of iron retorts, a second furnace with a series of air purifiers containing lime and caustic soda, and an air pump for forcing the air into the retorts and also for drawing off the oxygen, all connected by pipes, valves and appliances automatically worked and reversed by steam and hydraulic power. The barium charged in the retorts is heated to about 1,400° Fahr., and atmospheric air passed through the purifiers, where it is deprived of all moisture and carbonic acid, &c., is sent into the retorts at about 10 lbs. pressure, here its oxygen is absorbed by the barium, and the nitrogen passes off through a relief valve. This operation, known as per-oxidation, is complete in from five to ten minutes; the air is then cut off, and the purifiers placed out of action by the reversal of the valves, and by a further automatic readjustment of the connections; the air-pump then creates a partial vacuum in the retorts, and the oxygen thereupon given off by the barium passes into a gasholder ready for its subsequent compression. The process is continuous and indefinitely repeated, the barium being so little impaired that the charge only requires renewal at intervals of about every three years. The smaller cylinders into which the gas is compressed for delivery are solid drawn, rounded at the closed end, with a neck and delivery valve at the other, the larger are lap-welded and of increased substance; all are tested to withstand a pressure of 1½ tons to the square inch before they are filled or refilled when returned empty.

PAINTED WORKS, such as the panels of carriages, are first grounded, or carefully painted three or four times in good oil colour, and when thoroughly dry and hard, the surface of the paint is rubbed smooth with a lump of pumice-stone plentifully supplied with water; two pieces of pumice-stone are used and continually rubbed together to remove the paint accumulated on their surfaces. The finishing colour, which is frequently ground up in varnish instead of oil, is then laid on, and the panels after having had three or four coats of carriage varnish, (a description of copal varnish,) are carefully polished first with a rag supplied with pulverized pumice-stone and water, and then with rottenstone and oil on other rubbers: the worsted stocking being here likewise in great requisition for the purpose.

PALLADIUM.—Palladium, platinum and silver when inlaid in the limbs of mathematical instruments, are treated much the same as platinum, which *see*.

PARAFFINE OIL, a variety of naphtha distilled from petroleum. The ordinary illuminating paraffine oil of commerce, nearly or quite colourless and very fluid, is used by the engineer as a solvent to clean away caked and dried oil from the bearings and other portions of machinery, *see* OILS; it now almost supersedes *Brick oil* in the practice of the lapidary and seal engraver, for which it is more agreeable in use, cheaper, and in some cases more effective; it is also a lubricant used in turning glass with the diamond.

PARAFFINE or hydro-carbon mineral oil, yellow or amber in colour, used alone or mixed with some of the animal and vegetable oils as a lubricant, is obtained by distillation from the residue of the crude petroleum after all the burning oil has been separated; subsequently refined, to remove traces of bitumen, etc., by sulphuric acid and solutions of caustic soda and filtration.

NATURAL mineral oils, have greater body or viscosity and darker colour; used alone in lubrication or blended with the fatty oils; produced from some varieties of crude petroleum by a short distillation, only sufficient to drive off the more volatile portions of their burning oil, and subsequent hot filtration.

PASTES, or factitious gems made in coloured glass, are polished after the mode employed for the gems themselves, and the succession of the mills and powders used by the lapidary for the purpose is nearly the same as that described under CARNELIAN. Facets on pastes, are cut on a lead mill with flour emery, and polished on pewter with rottenstone, but the particulars of this part of the lapidaries' art will be found in Chap. X. The description of the principal *Factitious Diamonds* will be found under DIAMOND, article 10.

PEARL SHELL, or Mother of Pearl.—*See* SHELLS.

PEBBLES.—Although these differ much in their colour and general appearance, they may be viewed as varieties of Agate, and are treated as such, or in the mode fully described under the head CARNELIAN.

PERIDOT.—*See* CHRYSOLITE.

PEWTER is seldom polished; the articles when left from the turning tool or scraper, are burnished with plenty of oil, the oil is removed with a rag and whiting, and this is the only polish given. Pewter vessels are mostly cleaned with silver sand and water, or with liquids containing potash or soda, to remove the grease.

PEWTER is much used for laps and polishers by lapidaries, jewellers, watchmakers, and many others. The metal of old pewter plates is preferred, but tin unalloyed appears to be nearly identical in effect.

PHOSPHOR BRONZE, copper alloyed with from 4 to 10 per cent. of tin to which, when melted together, from 0·10 to 5 per cent. of phosphorus is added in the form of small pieces of phosphide of copper and phosphide of tin, the mass then thoroughly incorporated by stirring; introduced by Montifiore and Künzel about 1870, first used for cannon but now extensively employed.

Phosphor bronze is remarkable for its elasticity, tenacity and resistance to strains, in which respects it is considered to compare with gun-metal in the proportion of seven to one, it therefore affords increased safety with the same, or permits diminished weights and sections; for its resistance to wear from friction, in which some qualities excel steel, and for almost immunity from corrosion from acids and sea-water. Melted in plumbago crucibles it flows easily in iron or sand moulds, and with a good head it yields large or small sound homogeneous castings. It may be forged or stamped at a red heat or rolled cold into bars and sheets and drawn into tubes or wires, used for telegraphy and ropes. Employed in machinery where exceptional strength or resistance to wear or corrosion are desiderata; it long outlives gun-metal or steel for ships' propellors and in the construction and fittings of the vessels themselves, and the plates for the hulls of some are now made of its rolled sheets.

Phosphor bronze is planed, turned, filed and polished in the same manner as gun-metal.

PLANISHED POLISH.—A variety obtained by hammering or otherwise compressing the surfaces of silver, albata and other sheet metals and tin plate, sheets of iron coated with tin or zinc; the metal has its surface molecules driven into closer contact and acquires a burnished lustre beyond ordinary polishing; used for dish-covers, etc.

Mostly executed by hand-hammering the work held and twisted about on variously shaped stakes, their hardened steel and slightly convex faces and those of the hammers, kept scrupulously clean and highly polished. The blows are delivered so that the effect of every one just overlaps that of its neighbours; the process requires time and considerable practice, but an expert leaves a uniform hammer-hardened or polished surface, flat or curved, without any distinct indentations. The shaft of the hammer is sometimes attached to a spindle on centers worked by a lever to a foot treadle, after the manner of the *Oliver* or small lift hammer, Fig. 973, Vol. II., both hands are then at liberty to hold the work on the stake.

Dish-covers are also planish polished by friction and compression in a *Wheeling machine* worked by the hand and foot. This consists of a strong iron upright turned over into a bow above, much like a letter C, mounted on an iron base with spreading feet. A horizontal spindle passes through bearings in the upright and end of the bow, externally to which latter it carries semi-circular cams, segments of hardened steel discs with polished convex edges; and a vertical handle fixed to and hanging from the spindle within the bow, moved to and fro by the one hand, reciprocates the continuous partial rotation of the cam. The work is supported and twisted about upon a small convex edged roller mounted and turning on horizontal centers on the end of a cranked post, of which the lower straight portion is contained in a long cylinder in the base of the machine; a screw below it moved and fixed by a pedal raises the post and nips the work between the edge of the roller and that of the cam, and the post can be moved round by its cranked portion

to place the cam and roller parallel as to their axes or at angles as may be desirable.

PLASMA, which is a variety of Chalcedony, is polished like CARNELIAN.

PLASTER OF PARIS.—In removing the seams left from the mould a knife or scraper is first used and the work is then rubbed with Dutch rush, or fish skin previously softened in water. The cleaning off is best done before the plaster is dry.

PLASTER OF PARIS is made very closely to resemble ivory, by the following process, invented by Mr. Franchi, an Italian figure caster:—Plaster and colouring matter are employed in the proportions of one pound of superfine plaster of Paris, to half an ounce of Italian yellow ochre reduced to the finest powder, they are intimately mixed by passing them together through a fine sieve, after which the plaster cast is made in the usual way. It is first allowed to dry in the open air, and is then carefully heated in an oven, (one that is used for culinary purposes will answer,) the hot plaster cast when thoroughly dry, is soaked for one quarter of an hour in a bath containing equal parts of white wax, spermaceti, and stearine, heated just a little beyond the melting point. The cast on removal is set on edge that the superfluous composition may drain off, and before it cools its surface is brushed with a brush like that known by house painters as a sash tool, to remove any wax which may have settled in the crevices, and finally when the plaster is entirely cold, its surface is polished by rubbing it with a tuft of cotton wool.

Mr. Franchi's specimens in high relief were cast in a peculiar manner in elastic moulds; and although the above is the usual proportion of the yellow ochre for a medium tint, the quantity may be reduced or increased for paler or darker shades. The brown discoloured parts in old carvings in ivory are sometimes imitated in water colours with a camel hair pencil before the works are dipped in the composition, which entirely defends them from the action of the air, and permits them to be washed with soap and water if so required.

PLATE GLASS.—The polishing of this beautiful material is noticed in Chap. VI., Sect. 1.

PLATINUM is very difficult to file and polish, but these processes are not often required, as the great use of platinum is for chemical apparatus which are wrought almost exclusively with the hammer and soldered with pure gold. Platinum is sometimes inlaid in the limbs of mathematical instruments to receive the graduations, and then in filing this peculiar metal the file is generally moistened with oil to prevent it from tearing up. In polishing platinum the mathematical instrument makers use 1st, water of Ayr stone; 2ndly, blue stone; 3rdly, charcoal,—all with water; and 4thly, they lay the grain with charcoal and abundance of oil, in order that the metallic particles may be floated away. It is necessary to use *two* pieces of charcoal, and these are rubbed together at short intervals, in order to remove from the one, those minute particles of

metal which become embedded in the other, and that if allowed to remain would scratch the work.

POLISHING SLATES.—*See* HONE SLATES, articles 8, 9, and 14.

PORCELANOUS SHELLS.—*See* SHELLS.

PORPHYRY, deep red brown and dark green with pure white spots, is found in Northern Russia; it is successfully worked in Russia, Sweden, and also but n less quantities in England and France,—first with the pick and chisels, and afterwards by grinding it into form with emery and water applied through the medium of heavy rubbers, also of porphyry. As in other cases it is needful to employ a gradual succession of emery as to coarseness. It is also turned with the carbonate diamond tool and with Brunton's steel disc tools, *see* GRANITE, article 2; the final polish is obtained by rubbers of wood with flour emery, and wood covered with buff or felt and fed with crocus, much the same as in the treatment applied to granite. From the homogeneity of porphyry it is less difficult to manage than granite, but they each demand great time and patience.

The Elvans of Cornwall require similar treatment to porphyry and granite, between which they are systematically placed. By the lapidary porphyry is treated like AGATE or CARNELIAN.

POTSTONE, a magnesian mineral allied to Serpentine and Steatite, is very soft when first raised and then admits of being very easily turned with chisels of various forms. *See* Vol. I., page 166. The common practice in Germany for polishing the Potstone, is to use first sand and water, and afterwards tripoli and water, occasionally also rottenstone and oil for the highest gloss, the whole are mostly applied on woollen cloths.

When the lapidary polishes the Potstone, it is usually by the process recommended for Alabaster, unless from long exposure it has become hardened, and then it is worked as Carnelian.

PUMICE-STONE is a volcanic product and is obtained principally from the Campo Bianco, one of the Lipari islands, which is entirely composed of this substance. It is extensively employed in various branches of the arts, and particularly in the state of powder for polishing the various articles of cut glass; it is also extensively used in dressing leather, and in grinding and polishing the surface of metallic plates, &c.

Pumice-stone is ground or crushed under a runner, and sifted, and in this state it is used for brass and other metal works, and also for japanned varnished, and painted goods, for which latter purposes it is generally applied on woollen cloths with water.

PUTTY POWDER is the pulverised oxide of tin, or generally of tin and lead mixed in various proportions,—the process of manufacture is alike in all cases. The metal is oxidized in an iron muffle, or a rectangular box, closed on all sides

except a square hole in the front side. This retort is surrounded by fire and kept at the red heat, so that its contents are partially ignited, and they are continually stirred to expose fresh portions to the heated air; the process is complete when the fluid metal entirely disappears, and the upper part of the oxide then produced, sparkles somewhat like particles of incandescent charcoal. The oxide is then removed with ladles and spread over the bottom of large iron pans and allowed to cool. The lumps of oxide, which are as hard as marble, are then selected from the mass and ground dry under the runner, the putty powder is afterwards carefully sifted through lawn.

As a criterion of quality it may be said that the whitest putty powder is the purest provided it be heavy, some of the common kinds are brown and yellow, whilst others from the intentional admixture of a little ivory black are known as *grey putty*. The pure white putty, which is used by marble workers, opticians and some others, is the smoothest and most cutting; it should consist of the oxide of tin alone, but to lessen the difficulty of manufacture, a very little lead (the linings of tea chests), or else an alloy called *shruff* (prepared in ingots by the pewterers) is added to assist the oxidation. The putty powder of commerce of good fair quality, is made of about equal parts of tin and lead, or tin and shruff; the common dark coloured kinds are prepared of lead only, but these are much harsher to the touch and altogether inferior. Perhaps the most extensive use of putty powder is in glass and marble works, but the best kind serves admirably as plate powder, and for the general purposes of polishing.

2.—Putty Powder for fine Optical Purposes was prepared by the late Mr. A. Ross by the following method, the result of many experiments. Metallic tin is dissolved in nitro-muriatic acid, and precipitated from the filtered solution by liquid ammonia, both fluids being largely diluted with water. The per-oxide of tin is then washed in abundance of water, collected on a cloth filter, and squeezed as dry as possible in a piece of new clean linen; the mass is now subjected to pressure in a screw press, or between lever boards, to make it as dry as possible. When the lump thus produced has been broken in pieces and dried in the air, it is finely levigated while dry, on a plate of glass with an iron spatula, and afterwards exposed in a crucible to a *low* white heat.—— Before the per-oxide has been heated, or whilst it is in the levigated *hydrous* state, the putty powder possesses but little cutting quality, as under the microscope the particles then appear to have no determined form, or to be *amorphous*, and on being wetted to resume the gelatinous condition of the hydrous precipitate, so as to be useless for polishing; whereas when the powder is heated, to render it *anhydrous*, most of the particles take their natural form, that of *lamellar crystals*, and act with far more energy (yet without scratching), than any of the ordinary polishing powders. The whole mass requires to be washed or elutriated in the usual manner after having been heated, in order to separate the coarser particles.

Mr. Ross recommended the addition of a little crocus to the putty powder by way of colouring matter, to render it easier to learn the quantity of powder that remains on the polishing tool throughout the process of polishing lenses.

QUARTZ.—Pure silex, occurs both crystalline and amorphous and is polished after the mode described for CARNELIAN. The reader is also referred to the article CRYSTAL, by which name Quartz is very commonly known in the arts.

RAGSTONE.—*See* HONE SLATES, article 1.

RED STUFF.—A name applied by watchmakers to some kinds of crocus, or the oxide of iron, the manufacture of which is described under the head OXIDE OF IRON.

REPOUSSÉ OR CHASED WORK polishing.—When the design can be raised to the required relief between dies, under the drop hammer, or by hand chasing without re-annealing the sheet of metal,—the completed work is first *scoured* with Trent sand and water applied on rapidly revolving *bobs*, wheels made of bull neck about 12 inches diameter by 2 inches width of face, and then polished on similar wheels fed with rottenstone powder and oil. Common works produced in quantity have the sheets more or less scoured smooth before they are raised in the dies; after being struck they are boiled in soap and water to remove the grease, rinsed, dried and dipped for an instant in a bath of nitric acid and immediately again well rinsed in water, dried in hot clean sawdust and lackered.

Better class works in higher relief beaten from both sides which also have to be frequently annealed during their raising, are cleaned and polished subsequently to completion. Effected with Trent sand and then with rottenstone powder and oil on bull neck bobs of all diameters and forms of edge or face, held by their central holes on the conical screw end of the polishing spindle for their easy exchange to suit different parts of the work. Quicklime to remove the oil and lastly rouge both applied on linen mops (*see* WHEELS, article 66), completes the polishing. Usually only the higher portions of the design are polished and sometimes burnished, neither process being allowed to obliterate the tool marks which distinguish hand-chased work from that raised in dies; the depressed parts are generally left dull or matted from the fine or coarser chequered ends of the puncher.

RESIN OR ROSIN. *See* TURPENTINE.

RHODIUM, which is an extremely hard metal, is generally figured and ground on an iron lap, into the surface of which fragments of diamond have been hammered. As a temporary expedient rhodium may be polished on a brass lap with oilstone powder and oil, using a high velocity.

RHODONITE, manganese spar, pink or red flesh colour, found in the Ural Mountains; it is worked and polished like carnelian.

ROCK CRYSTAL.—*See* CRYSTAL.

ROTTENSTONE is a variety of Tripoli, almost peculiar to England, and proves a most valuable material for giving polish and lustre to a great variety of articles, as silver, the metals, glass, and in the hands of the lapidary even to

the hardest stones. It is found in considerable quantities both in Derbyshire and South Wales.

ROUGE.—*See* Oxide of Iron, articles 1 and 4.

RUBBERS.—The rubbers used in polishing often follow very nearly the form of the plane, the file, or the turning tool, accordingly as the respective artizans use these tools in their several avocations. For instance, the carpenter wraps glass paper around a square flat piece of cork; the engineer and others using files, fold emery paper upon that instrument, or use after the manner of the file square pieces of wood and metal fed with the several powders mixed with oil, and they also employ either the sides or the sloping ends of square slips of the polishing stones.

Many of the turned works in the metals, &c., are polished with pointed sticks of deal, by the ends of which the gritty substances are forcibly applied as the work revolves. The ivory worker wraps glass paper around small blocks of wood or cork, and applies moistened whiting on folded rag or on the sides and ends of slips of deal.

2.—The Rubber used by Masons and Statuaries is frequently a slab of grit stone, to which a handle is attached by means of an iron strap, or cement. Sometimes the handle is short and perpendicular, at other times long and horizontal, or inclined at a small angle or loosely attached by an eye bolt, and stones of two or three qualities from coarse to fine are used in succession. The same forms are also given to the handles of flat plates of iron and lead that are fed with sharp sand for polishing stone, or with emery for metal; and the plate may in this case be made of such a weight as to supply the required pressure, leaving to the workman alone to put it in movement to and fro upon the work with strokes evenly distributed throughout its surface.

3.—The Block or Cloth Rubber used for Marble, consists of a wooden block about 12 or 14 inches long, 3 to 6 wide, and 2 to 3 thick, a hole is bored through the wood at one end for a transverse stick or handle which projects, horizontally on both sides, and there are fillets of wood on the top by which lumps of lead are temporarily affixed to give the required pressure. Felted cloth nearly half an inch thick (called *nap*), is fixed below the rubber by folding the cloth a little way up the ends and nailing it, or thinner woollen aad also one or more layers of coarse linen cloth are also used according to the degree of hardness required.

4.—Large Cloth Rubbers for polishing marble are sometimes made of woollen or other rags placed in a rectangular iron frame, connected by two side screws which compress the rags into a dense mass, the surface of which is allowed to wear itself flat or it is levelled with a red-hot iron; sometimes the ring is entire and the rags are fixed by wedges, at other times the ring is in two parts and connected by side screws to produce the compression, and a socket is added for the attachment of the handle by which the rubber is moved.

5.—Small Cloth Rubbers or Rollers, used for various purposes in polishing, are commonly made of a coil of list or the selvedge of woollen cloth, wound

up spirally to the diameter of two to four inches and tied round tightly with string. They are usually covered with a cloth of some kind that may easily be renewed.

6.—Rubbers for French Polishing are made of little balls of wadding, (that used for ladies dresses), covered with a linen rag. The rubber is placed on the open mouth of the bottle which is then turned up, the varnish thus collected is covered with a second rag, and moistened with one or two drops of linseed oil, the varnish gradually exudes according to the degree of pressure given to the ball, which is of about the size of a walnut, and is thrown away after four or five minutes' use, as it hardens from the accumulation of the varnish and then scratches instead of polishing the work.

RUBY.—*See* Sapphire, of which it is considered to be a variety. For the preparation of ruby holes for the pivots of watches, *see* Vol. I., pages 178–9.

RUMBLE or Shaking Machine.—This is a contrivance used for polishing small articles principally by their attrition against each other. The rumble is often a cylindrical vessel with a side door for the introduction of the work, and is generally made to revolve as a churn by a winch handle or pulley, or is shaken endways by a crank in imitation of the mode of cleaning nails in a sack, and it is thence called a shaking machine. The following are some of the uses and forms of the rumble in mechanical works; uses:—

For scouring small castings to remove the sand coat; for brightening iron tacks previously to their being tinned; for polishing steel pens with sawdust after they are hardened and tempered; for polishing needles and brass pins with sawdust or bran: for polishing bone buttons with Trent sand; for polishing lead shot with black-lead powder; for drying small articles in sawdust after they have been annealed and pickled with acid, as in the blanks for coin; for dissolving gums in spirits of wine as in making lackers and varnishes —and to which processes might be added numerous others.

1.—Rumbles for Scouring malleable and small iron castings,—a strong square or hexagonal iron box, often of large size and sometimes of oak or other tough wood, with partitions proceeding from the internal corners about half-way towards the axial spindle upon which it revolves, and a door fixed by bolts and nuts in one of the sides. The work tumbles over from shelf to shelf and is cleaned by simple attrition. Plumbago, usually in the form of pieces of broken crucibles, is sometimes added towards the conclusion to give the work a gloss.

2.—Rumbles for Steel Pens.—A sheet iron drum 30 inches diameter by about 7 inches deep, the face a flat cone with a round central aperture for the introduction of the work and powders; revolving on the end of a horizontal spindle. The rotation is comparatively slow to avoid damage to the points of the pens from centrifugal force; the pens heap up on the off side of the drum and tumble over one another back to the lower part. Fine emery powder is used dry for the first grinding, and sawdust in a second drum for the polishing. A dull grey colour is given to steel pens after they have been

struck, hardened and tempered, by placing equal quantities of the pens and of fine sandstone, crushed to mixed irregular morsels varying in size from pin's heads to small peas, in a sheet iron barrel about 18 inches long by 12 inches diameter, slowly revolving horizontally; and this is followed in another barrel with a charge of half pens and half *pot*, similarly crushed fragments of plumbago crucibles, with a little lard oil, when the grey colour is required polished; the pens are afterwards cleansed from the dust in sieves or riddles. One operator manages about 30 barrels, each of which contains from 80 to 100 gross of pens in every charge.

3.—Rumbles for Tinning Hooks and Eyes, Tacks, etc.—A wrought-iron cylinder usually of half inch boiler-plate, about 12 inches diameter and 18 inches long, turned by a strap and pulley or, sometimes, by a winch handle, revolving on a long spindle on supports, one in front and the other behind a muffle furnace, so that the cylinder may be drawn out clear of the latter. The charge of work with dry powdered sal-ammoniac and a small quantity of grain tin is put in through a flanged door in the side of the cylinder, which is luted with clay and fixed with screws; and the work becomes equally coated with the melted tin after rotating in the heat for about an hour. The cylinder is then withdrawn, the door removed, and the contents let fall into a water trough just outside the mouth of the furnace, recharged and replaced in revolution.

4.—Shakers for Small Steel Work, such as weavers' mailes, oval washers half to seven-eighths of an inch long, punched out of steel or charcoal iron with a central hole for their attachment and a small round hole in each end to separate the threads which pass through them. These are polished smooth in strong round sheet-iron canisters about 12 inches long by 6 inches diameter, with a lid of wood, like a bung, lined with thicker iron and a thick iron bottom put on with a lap joint. The cylinder, about half filled with the work and a little emery powder and oil, is fixed by screws against its ends within a fork at the upper end of an arm which is pivoted below and reciprocated by a link to a crank; the contents are violently thrown backwards and forwards against the ends of the shaker, which portions from their construction are easily replaced when worn out.

SAND, which is nearly pure silex, is used in sawing and smoothing building stones and marbles, in glass cutting and in many other of the preliminary grinding and polishing processes. River sand and pit sand are in general sharper than sea sand, which is more rounded by attrition. Stone masons prefer the scrapings of roads that have been repaired with flint stones, the particles of which become knocked off and abraded by the traffic; and engineers sometimes employ grindstone dust, collected after turning the grindstone into form, or obtained by crushing the grit or sandstone with a hammer or pestle and mortar, as the grindstone dust cuts more sharply than Flanders brick, another form in which sand is employed.

2.—Trent Sand is collected from the banks of the river of that name which runs into the Humber. It is largely employed at Sheffield, and somewhat

throughout England generally, for polishing. This sand is remarkably fine and sharp and serves very economically many of the purposes of emery and other polishing powders prepared by art, it is very much used for Britannia metal goods.

The Sheffield cutlers are in the habit of making the Trent sand with water into balls two or three inches diameter. The balls when dry are burned for a few hours in the kitchen fire, and from being of a moderately dark brown, become brick red. The lumps are then crushed between the hands and passed through a fine hair sieve. The burnt sand is considered to cut quicker than the unburnt.

For common work they use the blue stone pulverized and sifted instead of Trent sand, that is, the blue grit stone, not the blue hone slate used for brass work, &c. Flanders brick when scraped may be used as a substitute for Trent sand, but being contaminated with the clay required in forming the brick, it cuts less keenly than the unmixed sand.

3.—Sand Paper is made with the common house sand, and only of one degree of coarseness, but in other respects exactly like glass paper, to which it is greatly inferior; the particles of sand are less angular and cutting than those of glass, when applied upon wood, &c., but on metals sand paper assumes a character intermediate between glass paper and emery paper.

4.—Sand in its natural state is employed as the abrasive agent in Mr. Tilghman's most interesting Sand Blast process on files and for embossing and engraving on metals and glass, for which *see* Chapter II., section 1, and Chapter IX., section 3. Chemically and mechanically compacted with other materials as a mass, it is employed for artificial grindstones with very successful results, for which *see* Grindstones, article 10, and Wheels, article 33.

5.—Tilghman's Iron Sand, small pellets of chilled iron used in abrading and sawing the harder stones, granite, porphyry, etc., *see* Granite, article 2, and Chapter V., section 3.

SAPPHIRE has been selected as one of the three general examples of lapidary work, described in this catalogue, namely Alabaster in explanation of the mode of working the softest stones and other allied substances, Carnelian in explanation of the modes pursued with stones of greater hardness than Alabaster, but inferior in this respect to Sapphire, the subject of the present article. Sapphires are alone exceeded in hardness by the diamond, which last is pre-eminent over all natural substances in point of hardness.

The previous articles on Alabaster and Carnelian may with advantage be here referred to, as containing much general information upon the lapidary art, which will also be more fully described in the 10th Chapter of this volume; but it should be here observed that the harder and smaller the gems to be wrought, the harder are the metallic laps or mills employed by the lapidary, and although sapphire may in truth be entirely wrought by the method employed for Carnelian, the following is the more usual as well as the more economical practice.

As gems are usually retained o as great size as their irregularities of sur-

face will admit, sapphires and many other gems are seldom reduced in size except by grinding, or as it is more commonly called, by *cutting* them. When however they are *divided* it is more commonly done by cleavage or splitting, than by slitting or sawing, which latter process when resorted to, is effected nearly as usual with an iron slicer fed with diamond dust, and lubricated with brick oil; the slicer for sapphires however is very much smaller than for general lapidary works, and is principally met with in the hands of watch jewellers.

Secondly, the lapidary commonly grinds and cuts the facets on sapphires upon a copper lap, supplied with diamond dust and brick oil, which cuts more quickly and delicately than the lead mill with emery; and 3rdly, these gems are polished upon a copper lap with rottenstone and water, the tool being jagged after the manner more fully described under the head CARNELIAN.

2.—The practice of the watch jeweller in making the pivot holes for watches in ruby and sapphire, is described in the first volume of this work, pages 178—9: *see also* DIAMOND, article 6: Diamond powder is used throughout for the cutting and polishing, and of three degrees of fineness, the coarsest on copper tools, the medium on glass, and the finest on pewter tools for the last polish.

Phillips says the sapphire has obtained several names amongst mineralogists and jewellers, dependent on its colour and lustre, namely,—

White Sapphire, when transparent or translucent.

Oriental Sapphire, when blue.

Oriental Amethyst, when violet blue.

Oriental Topaz, when yellow.

Oriental Emerald, when green.

Oriental Ruby, when red.

Chatoyant, or *Opalescent Sapphire*, with pearly reflections.

Girasol Sapphire, when transparent, and with a pale reddish or pale bluish reflection.

ASTERIA or *Star Sapphire*, exhibits 6 milk-white rays, radiating from the center of an hexagonal prism, and placed at right angles to its sides. The asteria is found in both the red and blue varieties of Sapphire, and is always cut *en cabochon* to show the figure.

All the above Sapphires, the Chrysoberyl, occasionally the Zircon and some others of the gems, are cut with diamond powder and polished with rottenstone, as above described.

3.—The translucent white sapphire is employed for the jewel holes of drawplates used for the production of the most minute and accurate gold, silver and copper wires. The stones prepared to the form of small flat discs are mounted in the lathe, and are first drilled with conical holes from both sides with a splinter of a diamond, which holes are allowed just to meet one another, and the aperture is then enlarged to the required diameter by grinding with delicate steel wires fed with washed diamond powder and oil. The tools are shown and described, page 178, Vol. I., and some further particulars are given in Chap. XII. of the present volume. The sapphire discs are subse-

quently mounted in rows, in the gradation of the diameters of their holes, inlaid in countersunk recesses in steel or brass plates, the edges of which are burnished over to retain them.

The most minute of these holes that the writer has had occasion to use measured but the two-thousandth of an inch, and smaller can be made. The skill and patience required for their production touches the marvellous, especially when it is added that the very few who have attained such perfection in this art, can produce holes of definite and accurate diameters increasing by ten-thousandths from two-thousandths of an inch diameter upwards.

The following "Draft scale" shows the gradations in the diameters of the sapphire holes required in drawing copper wires from two-hundredths down to two-thousandths of an inch diameter:—·0200, ·0180, ·0165, ·0150, ·0140, ·0130, ·0120, ·0110, ·0100, ·0092, ·0084, ·0076, ·0070, ·0064, ·0058, ·0053, ·0048, ·0044, ·0040, ·0037, ·0034, ·0031, ·0028, ·0026, ·0024, ·0022, ·0020.

SARD.—A variety of Chalcedony that is wrought by the lapidary like Carnelian.

SARDONYX.—*Idem.*

SATIN STONE or fibrous gypsum is treated much the same as Alabaster, but requires additional tenderness. *See* ALABASTER, article 3, also Vol. I., page 164.

SAW DUST is used by jewellers, brass finishers and others, in drying the metals after they have been pickled and washed. The saw dust of boxwood is preferred for jewellery on account of its freedom from turpentine or resinous matter; the saw dust of beech wood is next in estimation.

SCAGLIOLA, and other factitious marbles, are treated nearly the same as marble; but they generally require less labour because they are accurately moulded into form, and are somewhat softer than the generality of marbles; but when the materials are of unequal hardness the difficulty of the polishing is increased, from the softer parts wearing down too rapidly, and leaving the surface irregular.

SERPENTINE, when in large pieces, is treated like marble; when the serpentine is in small pieces, that are recent and soft, the lapidary employs much the same mode that he would in grinding and polishing Alabaster, (*see* article 3,) or the routine for Carnelian, when from exposure to the atmosphere the serpentine has attained its greatest degree of hardness.

SHAKERS.—*See* RUMBLES.

SHELLS.—A few remarks on the descriptive characters of the porcelanous and nacreous shells will be found, Vol. I., pages 118—120. Some of these shells are cut through to show their internal sections or structures, whilst others are simply polished exteriorly in their entire states, as specimens of natural

history or for their intrinsic beauty, some few of the shells are cut up in the manufacture of various useful and ornamental works. They are usually treated as follows:—

1.—Porcelanous Shells, which are generally univalve or single shells, such as the whelks, limpets and cowries, so far resemble porcelain or enamel as not to admit of being otherwise cut than with the apparatus employed by the lapidary; and accordingly, when porcelanous shells are divided to exhibit their sections, it is effected by the Slicer, with Diamond Powder.

The porcelanous shells do not generally require the coarser or grinding tools, as few of them present the rough coat or epidermis of the nacreous shells, and it is therefore only commonly needful to restore or increase their natural polish with the list or brush wheel of the lapidary. Putty powder may be used, but rottenstone, from its greater hardness, is more effective on porcelanous shells: similar wheels running in a vertical plane, such as those of the cutler and workers in horn and ivory, may be also used with equally good effect.

2. Nacreous Shells, which are generally bivalve shells, such as those of the various oysters, mussels, &c., are thus named from *nacre*, the French for mother-of-pearl, the covering of the *Ostrea margaritifera* of the Indian seas. The nacreous shells are much softer than the porcelanous, and may be sawn, filed and turned with moderate facility, but from the quantity of lime they contain they feel harsh and scratchy under the tools.

The pearl shell is much employed in ornamental art, and the usual course for its preparation into square, angular and circular plates and cylindrical pieces, is first, with saws of different and ordinary kinds; the pieces are then roughly shaped on the edge of a grindstone turned into grooves, and afterwards smoothed on the flat side of the stone: many use soap and water with the stone, to lessen its liability to become clogged. *See also* Vol. I., pages 119, 120.

3.—Pearl Shell in Detached Pieces, such as counters, silk winders, &c., immediately after having been ground, and when shaped on their edges, are smoothed with Trent sand or pumice-stone and water, on a buff wheel or hand polisher, and are finished with rottenstone.

The latter powder, although sometimes used with oil or water, is more frequently moistened with a little sulphuric acid, nearly or quite undiluted, this produces a far more brilliant polish, which probably arises from the partial destruction of the softer laminations of the surface, thus developing in a more decided manner the striated formation of the pearl shell, to which peculiarity of structure its variegated lustre is ascribed.

4.—Pearl Works Combined as in Boxes are most generally reduced to a flat surface by filing and scraping. First pumice-stone and then putty-powder are used on buff sticks with water, and the final polish is given with a buff stick and rottenstone moistened with sulphuric acid, this mode is available for inlaid works with gold or silver, but not for those having tortoiseshell or other substances that would be attacked by the acid. The buff stick is

expeditious, but for very flat surfaces, a flat deal stick covered with one layer of linen rag is preferable although slower.

5.—Turned Works in general only require fine emery paper, and then rottenstone on woollen rag with sulphuric acid, but oil may be used instead of the latter. Pearl buttons, mostly made in Birmingham, after being polished with rottenstone powder and oil are dipped in hydrochloric acid and then well rinsed in water. This like the sulphuric acid very slightly attacks the exposed edges of the softer layers of the material and fully restores the nacreous quality, temporarily subdued by the turning and polishing, and with it the original lustre.

6.—Pearl Handles for Razors.—The Sheffield manufacturers slightly rivet the handles together in pairs, after which they are 1st scraped, 2ndly "*sand buffed*" on the wheel with Trent sand and water, 3rdly "*gloss buffed*" on the wheel with rottenstone and oil, or sometimes with dry chalk rubbed on the same wheel, and 4thly they are "*handed up*," or polished with dry rottenstone and the naked hand.

7.—Pearl Shell, when polished by the lapidary, is treated in the mode followed with Alabaster. *See* article 3.

8.—Shell Cameos.—A very suitable material for cameos is found in the various conch shells or *Strombs*, the substance of which consists of two distinct layers of different colours, textures and hardness, and which may be considered respectively to partake of the nature of nacreous and porcelanous shells, the chemical compositions of which were noticed in Vol. I., page 118. The outer coat or layer in the most suitable specimens of conch shells is nearly colourless, of uniform texture, and like that on the nacreous shells admits of being readily operated upon by steel cutting tools, which may be made to produce a smooth and well-finished surface, this outer layer is therefore suited for the carved parts of cameos, the ground being formed of the under layer of the shell, which in the most suitable kinds is of a dark colour and allied to the porcelanous shells, being somewhat brittle and so hard and compact as not to admit of being readily cut with steel tools.

The best kind of conch shell for carving into cameos is found on the Southern coast of America, and also on the coast of the West India Islands, and commonly known as the "*black conch;*" in these shells the contrast of colour is the most decided, the under layer being very dark or nearly black, especially in the old or full grown shells, which are the hardest and most compact, and also possess the greatest amount of the white or outer layer, the part to be carved. In the pink conch shell the contrast of colour is not so great, and as it does not at all resemble the onyx in which antique cameos were cut, it is but little used for the best works; nevertheless, some very beautiful specimens of carving on the pink conch shell are to be met with, and the delicacy of the colours gives a very pleasing effect. The most suitable shell having been selected it is cut into pieces of the required forms for the cameos; this process, which must be cautiously performed, is best effected by means of the slitting mill fed with diamond powder, described in the chapter on Lapidary Work, but the cutting may be also effected with a blade of iron or steel, such as a

thin table knife blade notched to form teeth, and fed with emery and water, a process similar to that by which the stone mason cuts slabs of freestone and marble with a smooth blade of iron fed with sand and water. The piece of shell having been cut out is next carefully ground to the general form of the cameo, as square, lozenge, elliptical or other shape, upon an ordinary grindstone, the face and back of the shell being also levelled and reduced to the appropriate thickness. A slip of Turkey oilstone may be used with advantage to give the last finish to the edges of the shell after the upper white layer has been removed from it, for when the shell has lost the support of the white layer, it will be found that the coarse cut of the grindstone will fill it with minute cracks, which frequently spread over the surface after the cameo has been some time finished.

A piece of shell of the desired form and thickness having been prepared it is cemented on a block of wood about 3 inches diameter, or of a convenient size to be grasped firmly in the hand; care being taken to place the piece of shell level and near the center of the block, in order that all parts of the cameo may be operated upon with equal facility. The contour of the subject to be carved is next sketched on with a pencil and its outline scratched in with a steel point, after which all the surrounding white substance is removed with files and gravers before proceeding to develop the figure by means of the small tools. A very convenient form of carving tool for this purpose may be made of pieces of steel wire about 6 or 8 inches long, flattened at the ends and hardened; ground to an angle of about 45 degrees, and carefully sharpened on an oilstone. The largest tools may be made of wire about $\frac{1}{8}$ of an inch diameter; smaller wire will serve for tools of a medium size, but for the smallest tools an ordinary darning needle left quite hard and ground to the same angle, when inserted in a wooden handle, will be found very useful in deepening the finer lines. The advantage of this form of tool consists in the absence of any angles that would be liable to scratch the work, and a tool thus formed admits of being used either as a gouge, or as a chisel, according as the flat or round side is brought to act on the work.

To guide the tool in the act of cutting, the left hand should grasp the block upon which the cameo is cemented, the thumb being placed close to the cameo; the tool held in the right hand should be rested against the thumb of the left hand as a fulcrum, upon which the tool may be moved as a lever in short arcs of the circle, with a scraping action which removes the material as a powder, care being taken that every cut is made obliquely downwards towards the black ground; should any of the cuts be made towards the surface, or even parallel therewith, there is danger that small pieces may be chipped off which would be destructive to the cameo. As in all other processes of producing form by reduction, the general shape should be first wrought with care to leave every projection rather in excess, to be gradually reduced as the details and finish of the work are approached. To render the high parts more distinct during the process of carving, it is usual to mark them slightly with a black lead pencil. Throughout the cutting great caution is observed that in removing the white thickness the dark ground is not damaged, as the natural

surface of the dark layer is far superior to any that can be given artificially; indeed, should the ground be broken up at one part, it would be requisite from its lamellar structure to remove the entire scale or lamina from the whole surface, a process that will be found very tedious, and much more difficult than the separation of the white from the black thickness.

In order that the finished cameo may possess a distinct outline at all points of view, it is desirable to adopt the system followed in antique cameos, namely, to leave all the edges of the figure quite square from the ground, and not gradually rounded down to the dark surface; should this latter method be followed, it will be found that the outline is in many places undefined, owing to the colour of the white raised figure of the cameo gradually merging into that of the dark ground; this evil is entirely avoided by leaving the extreme edge of the figure quite square, for about the thickness of one-fiftieth of an inch. The surface of the cameo should be finished as nearly as possible with the cutting tools, as all polishing with abrasive powders is liable to remove the sharp angles of the figures, and deteriorate the cameo by leaving the form undefined. When, however, the work has been finished as smooth as possible with the cutting tools, the final polish may be given with a little putty powder used dry, upon a moderately stiff tooth brush, applied with care, and rather to the dark ground than to the carved surface: this is the concluding process; after which the cameo is ready for removal from the block prior to mounting.

SILEX is the basis of tripoli, sandstones, sand and some other polishing powders. It constitutes from about 65 to 98 per cent. of those substances, and is the fourth or fifth of the polishing materials in the order of hardness,—silex being preceded by carbon and alumina, and probably by the oxides of iron and tin. *See* page 4 of this volume.

Dutch rush and charcoal owe their abrasive qualities, and the enamel of teeth its hardness, to the silex they respectively contain.

See also CRYSTAL and QUARTZ.

SILICATE OF SODA,—a viscous fluid, in appearance like a thick solution of clear brown gum, made by dissolving common flints with heat under pressure in a strong solution of caustic soda. Largely used for chemically cementing together sand for artificial stone and in the manufacture of emery wheels.

Flints gathered from the shore and, therefore, naturally rubbed free of their external rind, known as French flints, are preferred to those taken from the chalk, but both kinds are used. These in the proportion of about three bushels of flints to every ten gallons of caustic soda, of about 75 specific gravity, are placed in a strong vertical iron boiler closed in by a cover, luted down, and provided with a vertical pipe and a stop cock. This vessel is contained within a second similar boiler or jacket, and a constant supply of steam at from 50 to 60 lbs. pressure is admitted between the two. On the completion of the boiling the stop cock is turned and the resulting solution escapes upwards into an open settling tank; when the chalk and other earthy impurities have deposited below the level of an outlet pipe, the supernatant fluid is allowed to flow

down to an evaporating tank where it is boiled by a steam coil to drive off the major portion of the water.

SILVERSMITHS' work, after having been filed is generally rubbed, 1st with a lump of pumice-stone and water, 2ndly with a slip of water of Ayr stone and water, 3rdly a revolving brush with rottenstone and oil, 4thly an old black worsted stocking with oil and rottenstone, and 5thly it is finished with the hand alone, the deep black lustre being given with rouge of great fineness. The corners and edges are often burnished with a steel burnisher, which is lubricated with soap and water if at all.

In this case and in all others of polishing with the naked hand, it is generally found that women succeed better than men, and that some few, from the peculiar texture and condition of the skin, greatly excel in the art of polishing. The skin should be soft and very slightly moist, as the polishing powder then attaches itself conveniently, and there is just sufficient adhesion between the hand and work to make the operation proceed rapidly. A dry hand becomes hard and horny, and is liable to scratch the work, and excess of moisture is also objectionable, as the hand is then too slippery.

2.—The Plated Reflectors for Light-houses are cleaned with rouge, which is dusted on from a muslin bag, and rubbed over them with a clean dry wash-leather. A thin film of oxide will nevertheless occasionally form on the surface of the reflector, and this is removed with a piece of leather, with rouge moistened with spirits of wine, which dissolves the oxide, after which the dry rubber is applied as above.

SKIVE.—The iron lap used by the diamond polishers in finishing the facets of diamonds for jewellery. The skive is charged with fragments of diamond powder that are burnished into its surface.—*See* Diamond, also page 176, Vol. I.

SLATE.—The ordinary slate used for building purposes does not admit of being highly polished, but it is rubbed smooth, first with an iron plate fed with sharp river sand and water, and then with lumps of gritstones, of which two or three kinds gradually finer one than the other are used with water. The rubstones employed, depend principally on their relative abundance in the respective districts.

A lump of pumice-stone leaves a grain on slate suitable for writing upon, and the greyness is removed either by a slight rub of oil, or what is better a wash of common writing ink allowed to dry on. A disc of slate cemented to a wood chuck is useful to the amateur for receiving in the lathe rough sketches of eccentric patterns, and slate also serves for drawing boards.

As noticed in Vol. I., page 165, slate is employed for chimney pieces, internal decoration and furniture, in which case it is rubbed smooth, then japanned like black and other marbles and of all colours and devices, after the manner of tea trays; when the objects have been baked to harden the japan they are first smoothed with pumice-stone, and then polished with rottenstone, after the ordinary mode described under Japanned Works.

SLICER.—*See* SLITTING MILL.

SLITTING MILL or the Slicer, is a very thin sheet-iron disc, the edge of which is charged with diamond powder, and lubricated with brick oil. The slicer is the circular saw of the lapidary. *See* the chapter on LAPIDARY WORK.

SNAKE STONE.—*See* HONE SLATES, article 3.

SOAP AND WATER as also soda and water are generally used to lubricate the tool in turning steel, iron, copper and lead. Soap and water has also been recommended for use on hones instead of oil in setting razors and surgical instruments as being more effective and cleaner. The hone to be wiped clean with a wet sponge and the lump of soap also wetted, is to be rubbed on until it produces a thin lather, which is to be sponged off when the hone is laid by.

SOFT WOOD.—*See* WOOD.

SPECULAR IRON ORE.—*See* OXIDE OF IRON, articles 5 and 6.

SPECULUM METAL.—The mode of grinding and polishing this alloy will be noticed in Chapters VI. and VIII.

SPHERES.—The process of grinding and polishing the small metal spheres used for the reduction of friction in bicycle and other bearings, which is an extension of that for the production of MARBLES FOR CHILDREN, see page 81, is described Chapter VIII., section 1, and is followed by particulars of the method of grinding accurate spheres contrived by the late Mr. Henry Guy.

2.—BILLIARD BALLS.—The practice in turning and the exactness of the gage for the precise spherical truth of the billiard ball, supplied by the rotation of the lathe, are described Chapter XI., Vol. IV.; the same precautions are followed in polishing to avoid deteriorating the truth of the ball as left from the turning. 1st, the ball is *papered;* it revolves with rather more than half its surface projecting from the wood chuck, and a small square of fine glass paper held around it in the hollow of the hand, is once or twice swept all over the hemisphere from its circumference to its center; the ball is then released from the chuck by the fingers and replaced to revolve upon the *same* axis but with its other half exposed, which is papered in the same manner. Two halves of the ball are then similarly treated when revolving upon an axis at right angles to the first; followed by rechucking upon several fresh axes at different angles, at all of which the ball is equally papered first on the one half and then on the other. The glass paper is held in light contact, and the aim is to abrade a small and equal quantity from all over the entire hemisphere and then to remove a precisely similar equal quantity from the companion half upon the same axes. The variation in the axes of revolution causes the glass papering done upon any one to cross and correct that done upon all others that have preceded it; and as the ball was already a sphere prior to its polishing, the pencil line struck around its circumference previously to every change of axis during the turning is dispensed with, and the eye and hand are depended upon when

reversing the ball end for end and replacing it at fresh angles. 2ndly, the ball is polished half at a time and upon numerous axes as in the papering, with washed or carefully sifted whiting and water of the consistence of cream, applied upon a single or two thicknesses of linen rag held in the same manner and with the same precautions for equality of action as with the glass paper; because with this far less active material it is nevertheless easy to polish the ball out of perfect truth. 3rdly, the ball is washed with clean water and when thoroughly dry is polished to its final lustre with a few drops of neats-foot oil applied on rag like the whiting, the ball in revolution as before.

STEATITE, especially when first raised, is a soft unctuous magnesian mineral, and is thence called soapstone, but like Potstone, and Serpentine, which it nearly resembles in its constituent parts, it becomes considerably harder by exposure to the air. Steatite when recent, may be treated by the method practised in Germany with POTSTONE, which see, and when indurated, by the same routine that is employed for alabaster by the lapidary. Many of the Chinese idols and other figures, are carved in Steatite, which has thence been called Figure Stone. *See* Vol. I., page 166.

STEEL.—The parts of machinery made in steel, are polished as described in the general article MACHINERY, in this Catalogue.

STRAGGLING.—A term indicating the mode of dressing the surfaces of grindstones, which is fully described under WHEELS, article 16.

SURFACES.—The principal modes of grinding plane surfaces are described in Chapters IV. to VI.

TESSERÆ.—*See* MOSAICS.

TIN is seldom polished except when in the form of tin-plate, for which purpose, rottenstone and oil, or whiting and oil may be used, dry whiting being lastly applied to remove the grease.

Works in solid tin are occasionally made by pewterers, and polished the same as that useful alloy. *See* PEWTER.

TIN, OXIDE OF.—*See* PUTTY POWDER.

TOPAZ; of the Brazilian Topazes, there are the yellow, which is best known, the blue, and the white, the latter being more commonly called the Mina Nova. The Brazilian Topazes are worked like Carnelian, the Oriental Topaz, which is in fact a yellow variety of Sapphire, is treated like other Sapphires, and is cut into facets with diamond powder and polished with rottenstone, as more fully described under the head SAPPHIRE. The difference in hardness of the two gems is satisfactorily accounted for by their analysis, as the Brazilian Topaz contains about 50 per cent. and the Oriental about 98 per cent. of alumina; this substance being next in hardness to the diamond.

TORTOISESHELL.—The covering of the *Testudo imbricata*, and on the working of which the reader is referred to Vol. I., pages 126—135, is usually polished after one of the following modes:—

1.—Tortoiseshell Handles for razors and penknives, combs, spectacle frames, and many similar works, after they have been sawn out and moulded into form, *see* Vol. I., page 130, are smoothed with a float or single cut file technically known as a *quannet*, *see* Vol. II., page 838, and then shaved or scraped smooth with a scraper like that used by joiners. Cutlers often use an old razor blade the edge of which has been sharpened at right angles, by placing the blade perpendicularly on the oilstone.

The works are then very sparingly polished on a wheel covered with thick buff leather, such as the bull neck, or sea cow, and fed with calcined Trent sand and oil, *see* article on Horn, and they are finished on a similar wheel supplied with rottenstone and oil, occasionally the latter wheel is alone used. Razor handles and some other works are often *handed up*, or finished with the naked hand and dry rottenstone, and works required to be very nice and flat are more generally treated as follows:—

2.—Flat Works in Tortoiseshell, such as card and needle cases and others that require to be kept flat, are floated and scraped as above, afterwards pumice-stone, putty-powder and rottenstone on three different buff sticks are successively employed, and all generally with water but sometimes with oil, as the treatment varies according to the material inlaid in the tortoiseshell, which is lastly finished with the hand and rottenstone or whiting. When the works have mouldings and sharp edges that would be rounded by the buff stick, the same materials are used on slips of wood filed to the appropriate forms.

3.—Tortoiseshell when turned in the Lathe is cut with the tools used for hard wood, and although the material is soft it rapidly blunts their edges; it is usually smoothed with fine glass or emery paper, and finished with rottenstone and oil, on linen or woollen rag.

TOUCHSTONE is a compact black basalt or Lydian stone of a smooth and uniform nature, and is used principally by goldsmiths and jewellers as a ready means of determining the value of gold and silver by the touch, as it is termed—that is, by first rubbing the article under examination upon the stone, its appearance forms some criterion; and, as a further test, a drop of acid, of known strength, is let fall upon it, and its effect upon the metal denotes its value.

TRENT SAND.—*See* Sand.

TRIPOLI, according to Phillips, is an earth of a grey yellow or red colour, used in polishing, that was first introduced from Tripoli in Africa, whence its name, but it is found in France and elsewhere, and it is said to contain nearly 90 per cent. of silex.

2.—Red Tripoli has been largely prepared from a brick earth found near Battle in Sussex. When burned in lumps it is nearly as heavy as emery stone, after

which it is ground and sifted and presents the appearance of crocus, but is coarser and is used for similar but inferior purposes.

A Red Tripoli prepared by calcining and pulverizing *Clunch* or *Curl Stone*, found in the coal and iron districts of Staffordshire, &c., is highly recommended by Mr. Gill. *See* the articles on the OXIDES OF IRON.

3.—YELLOW TRIPOLI, sometimes called French Tripoli, is employed for polishing generally, and amongst other substances for light-coloured hardwoods that would be stained by the absorption of darker powders into their pores. A large quantity of fine yellow tripoli was obtained in digging the canal in the Regent's Park, London; some additional particulars are given on this subject at the conclusion of the article on VARNISHED WORKS.

TURKEY OILSTONE.—*See* OILSTONE.

TURPENTINE.—Oil and spirits of turpentine are distilled from the sap of the *Pinus palustris* and other varieties of the pine tree. Large deep pocket-like excavations are made in the trunks about a foot from the ground and fill with the turpentine which exudes from the surface of the wood above, a few feet of which is deprived of its bark and scored or channelled. The flow is impeded after a few days by the coagulation of the resin, but recommences immediately that is scraped off the wood, done every time the pockets are emptied of their contents; the trees are drained every spring until exhausted, each year's yield declining in quality.

Oil of turpentine is extracted from the crude fluid in ordinary stills; it is first gradually heated to from 212° to about 500° Fahr., until all the native and accidental water is driven off, with which methylic spirits and certain acids also come over. A small continuous supply of cold water is then admitted to the still, its quantity regulated to prevent the heat exceeding 316°, the boiling point of turpentine; the steam and oil of turpentine then come over together and are received and separated in a vessel, from which the water is drawn off at the base and its level thus kept below the outlet for the turpentine above. Spirits of turpentine, called also essence of turpentine, is the oil further rectified by repeated distillations over chloride of calcium, it is bright, clear, and liquid as water; like the oil it is used in numerous manufactures,—it is burnt in lamps under the name of camphine.

RESIN or ROSIN is the residue left in the still after the oil of turpentine and the water have been carried over: this whilst still hot and fluid is run off from the still passing through a strainer, to cleanse it from pieces of bark and refuse, on its way to a vat from whence it is barrelled. The quality of the crude turpentine and the skilful management of the heat in distilling the oil determine the quality of the resin. Crude of the first year known as "virgin dip" gives the best oil and a bright clear light coloured resin; "yellow dip," the yield of the subsequent years, second and third qualities darker in colour. An inferior and almost black resin is obtained from the scrapings of the dried gum on the trees. Further distillation of the resin after all the turpentine is extracted yields a fluid known as ROSIN OIL, which, among other employ, is

mixed with train oil for railway grease; the mixture after a period of repose deposits a solid sediment which has to be removed from the portion used.

TURQUOISE.—The Oriental Calaite, or Turquoise, is a comparatively soft gem found in the mountainous districts of Khorassan in Persia, those of a dark blue colour being the most esteemed. They are somewhat rarely engraved as seals, but are mostly used by the Persians, nearly of their natural forms for ornamenting bridles, the handles of scimitars, &c., as the Orientals remove in general but little of the weight of gems in cutting and polishing them, which they effect on corundum wheels, although they are well acquainted with the use of diamond powder as an abrasive for such works as require it.

In Europe the turquoise is generally cut and polished by the method pursued with alabaster and other soft and rounded stones.

TURTLESHELL is worked and polished the same as TORTOISESHELL, *which see.*

VARNISHED WORKS of the finest kinds, such as the wood work of harps, are thus treated. The wood is covered with about six layers of the white hard varnish, and allowed thoroughly to dry between each, this entirely fills the pores of the wood; the face is then rubbed quite smooth with fine glass paper. The ornamental painting is then done, after which about eight or ten coats more of varnish are laid on, and at every third coat the surface is rubbed with fine glass paper to remove the brush marks.

When all the varnish is put on and has become hard, the surface is rubbed with fine pumice-stone powder and water on woollen rags, the work is allowed to stand for a day or two, and is then polished with yellow tripoli and water, after which it is washed quite clean with a sponge and wiped dry with a clean wash leather. The varnish is now touched at a few places with the finger smeared with fine rendered tallow, which is then thoroughly rubbed all over with the ends of the fingers; clean wheat flour is dusted over the work, and also well rubbed in with the fingers; and after the removal of the flour, the surface is slightly rubbed with a clean old silk handkerchief, which completes the splendid lustre given to these instruments.

It should be observed that the rottenstone of commerce is sometimes ground very fine with a stone muller before use, and so also is the tripoli. The tripoli used by the Messrs. Erat, from whom these particulars were gathered, was obtained from the earth removed in digging the canal in the Regent's Park, London; the dry lumps when cleared from the clay by which they were surrounded, were of a light brown yellow, and as hard as a stone so as to require to be crushed with a hammer previously to being ground.

VULCANITE, a hard black and homogeneous substance made of masticated India rubber impregnated with sulphur under great heat, and pressed and rolled into blocks and sheets; used for surgical and numerous other appliances, but most largely for electrical apparatus. Vulcanite is worked and turned like the hardwoods; scraped and filed smooth, and receives a delicately fine even surface, rather than a polish, first, with emery paper or the powder on

rubbers with oil, and is finished with rottenstone powder and oil applied in the same manner, and then the dry powder, which many apply on the palm of the hand.

WASHING or the separation of powders into different degrees of fineness by washing over or elutriation.—On the advantages of the careful separation of the polishing powders some remarks were offered in the introduction to this division of the work; the practice of washing, which is within the reach of every one, is described in this Catalogue under the head EMERY, articles 2 to 5.

The author has been in the habit of washing some others of the polishing powders, but generally into two sizes only of each; the times employed for their respective depositions, which are somewhat influenced by the specific gravities of the substances, are subjoined.

POWDER.	No. 1.	No. 2.
Chalk	1 minute	2 minutes
Crocus	10 seconds	30 seconds
Oilstone Powder . . .	30 ,,	3 minutes
Pumice-stone Powder . .	30 ,,	3 ,,
Rottenstone	30 ,,	3 ,,
Tripoli	30 ,,	1 ,,

Washing is constantly employed in metallurgy, for the separation of the metallic particles from the earthy matters in the pounded ores; in the manufacture of porcelain for the separation of the coarse and large particles from the fine clay, and prepared flint, therein used, and in the preparation of polishing powders and some drugs.

WATCHWORK.—As regards the parts in steel, *see* MACHINERY, article 13, and the parts in brass, *see* BRASS, article 6.

WATER OF AYR STONE.—*See* HONE SLATES, article 3.

WAX OR BEESWAX, the material secreted by the honey bees to form their cells; a nearly similar substance occurs in vegetable nature, and plentifully in the berries of the Myrica tribe. Beeswax is very generally preferred unrefined, as being less liable to adulterations; the comb deprived of its honey is melted by simple boiling in water and cast in moulds into lumps of all shapes weighing from 10 to 30 lbs.; the cakes have a crystalline-like fracture of a tawny orange colour, due to impurities and the remains of the honey and pollen. It melts into an oily, dusky yellow-coloured fluid which commences to solidify directly it cools below 140° Fahr.; it entirely dissolves in ether, benzine, bisulphide of carbon and in hot oils, and almost in alcohol and turpentine. Low-priced beeswax is adulterated with yellow ochre, pea flour, brick dust, red lead, &c., all of which deposit if the wax be melted, usual for the separation of impurities before mixing any compounds.

2.—WHITE WAX.—Bleaching by chlorine or chemicals deteriorates the wax for

burning and other purposes, and after its purification beeswax has the colour destroyed as follows—(i.) The wax is repeatedly boiled and stirred in water until by elimination of the foreign matters the colour is reduced to a light grey; it is then run from the steam pan through a cullender perforated with a few oblong slits into the one end of a long trough of cold water, the other end of which carries a wooden roller partly immersed in the water, upon which the solidified thin wax ribbons are wound. (ii.) The straightened out ribbons are bleached by about three weeks' exposure to light and moisture in the open air, supported across lines stretched to posts and rails; they are turned over every day and frequently watered as in bleaching linen. The whitest wax is obtained by several times remelting and reproducing the ribbons, so that by these new surfaces the whole substance of the wax may be exposed to the sunlight and air. About 10 per cent. of rectified turpentine is mixed with the melted wax by some refiners, who consider it hastens the bleaching, during which process the turpentine evaporates. Subsequently the ribbons are remelted and run through fine sieves into moulds into the form of small flat discs. White wax is adulterated with starch, detected by dissolving in turpentine which will not take up the starch, refined tallow and ceresine, a mineral wax prepared from paraffine, the presence of the former is shown by the benzoic acid in the tallow obtained by distilling a sample, and the latter by treatment with sulphuric acid which destroys the true but leaves the mineral wax untouched.

WELCH CLEARING STONE.—*See* Hone Slates, article 10.

WHALEBONE.—Some of the applications of this peculiar substance are noticed in Vol. I., pages 135-6. To polish whalebone it is scraped with steel scrapers or pieces of window glass, rubbed with emery paper, and then with woollen cloth supplied with tripoli or rottenstone. The polishing lathe is also used for whalebone, which is then treated like horn or tortoiseshell.

WHEELS.—In almost every branch of the manufacturing and mechanical arts, the processes of abrasion are advantageously fulfilled by rotatory motion applied to various grinders and polishers. These are generally circular discs, made of a great variety of substances, usually fed with abrasive powders. Most of these apparatus, with the exception principally of the grindstone, are known by the cutler and the tool maker as *wheels;* by the mechanician as *laps*, by the lapidary as *mills*, by the optician as *tools*, and also by many other conventional names; the first name, or Wheels, has been selected for the title of this article as being the most general. A few words will be first offered on the principal modes in which these wheels are employed.

1.—General Mechanical Arrangements.—*Cutlers and tool makers* place the axes of the wheels *horizontally*, and employ both for the grindstone and the polishing wheels the same framework or apparatus. *Mechanicians* frequently employ nearly the same arrangement as cutlers and tool makers, and in some few cases mount the laps and wheels as adjuncts to the lathe. *Seal Engravers* always use a small lathe mandrel, to which their delicate

grinders are attached. *Lapidaries*, unlike the above-named artizans, mostly place the axes of their mills *vertically*, and frequently drive them by the left hand, as will be explained. *Opticians* fix their spherical tools for grinding and polishing lenses, horizontally, on the top of a fixed post, and rub the lenses or specula upon the same with an elliptical motion given by the hands, and they continually walk round the post, to change the direction in which the grinder and tool successively meet. *See* Chap. VIII.

These and other mechanical arrangements, will however be touched upon in the course of the chapters immediately following, and therefore, it is intended at this place principally to direct attention to the abrasive apparatus, and which will be classed under seven heads, namely:—

A.—Wheels of Natural Stone such as Grindstones.
B.—Wheels of Factitious Stone, and of Emery or Composition Wheels.
C.—Wheels of Metal, or Metallic Laps.
D.—Wheels of Wood, or Glaze Wheels.
E.—Wheels of Leather, or Buff Wheels.
F.—Wheels of Cloth, or Cloth Wheels.
G.—Wheels of Bristles, or Wire, or Brush Wheels.

In every case but the first, the cement, metal, wood, leather, cloth, bristles or wire, are to be viewed solely as the vehicles or carriers by which the abrasive matters or powders are applied. In speaking of these apparatus, their structure will be first noticed, and some observations on the modes of using them and keeping them in order, will be then subjoined.

Section A.—Wheels of Natural Stone, such as Grindstones.

2.—The reader is referred to the article Grindstone for the description of the principal varieties of the sandstones or gritstones used in the mechanical arts for various purposes, the most important of which uses is the grinding of various cutting tools; indeed the removal of the grindstones from our workshops would be an almost insuperable loss. The principal modes of employing grindstones are as follows:—

3.—Grindstones used by Hand.—In the most primitive method the tools to be ground are simply rubbed on the quiescent stone, as stonemasons and others whet their chisels on the foot pavement after the manner of sharpening a tool upon a hone; or smaller slabs of gritstones are employed after the manner of the butcher's steel, as in whetting a scythe with the rubstone. It is however very far more usual to fashion the grindstone as a thick disc, or very short cylinder, and to perforate it with a square central hole or eye, for the iron axis upon which the stone is mounted and put in rotation, as described in the succeeding paragraphs.

4.—Grindstones moved by Winch-Handles.—These are the simplest of all rotary grindstones, and must be familiar to almost every one; when the stone does not exceed about one foot in diameter, it is commonly mounted on the upper edges of the little wooden box or trough which serves both to support

the pivots of the axis on which the stone revolves and to contain the water with which it is moistened. The one extremity of the spindle is squared for the winch-handle, the central part is squared for the convenience of wedging on the stone with wooden-wedges, and there are cylindrical necks or pivots on the axis, the bearings for which are sometimes of hard wood such as lignum vitæ, or far better of metal. In the most common form, two iron staples which surround the pivots are simply driven into the top edges of the wooden trough; in the best form the trough and bearings are both in metal, and there is a small bar or rest parallel with the axis for supporting the tool which is held in the right hand, whilst the stone is turned with the left. The stones thus mounted sometimes measure nearly as much as 20 inches in diameter, and are used by general artizans for small tools and also by opticians for fitting in the lenses of spectacles.

5.—Ordinary Grindstones used by Carpenters, Smiths, and many others, which stones vary from about two to four feet in diameter, are often mounted very nearly the same as the last so as to be worked with a winch-handle, which is then however turned by an assistant, but the frames for these larger stones are continued to the ground, or are sometimes let into the ground, and between the four legs of the frame is placed the water trough. In these cases, there is no objection to the stone dipping a little way into the water whilst it revolves, as the surface velocity of the stone can be scarcely so great as to cause the water to be thrown off by the centrifugal motion; but the stone should not be allowed to remain immersed at one particular part, or it will be there softened and become more disposed to wear irregularly; the trough is consequently often suspended on a hinge or joint at the one extremity, and hung up by a chain at the other, so that it may be occasionally raised for moistening the stone.

6.—Grindstones moved with Treadles.—For stones from about 20 to 40 inches diameter this method is highly to be commended, as the stone whilst in rotation, then supplies enough momentum to act as a fly-wheel, and in such cases it is only needful that some part of the iron axis for the stone should be formed as a crank of three or four inches radius, from which a connecting rod or crank hook should descend to the treadle, jointed to the two back feet of the framework, nearly as in a turning lathe. A higher velocity may be thus given to the grindstone than with a winch-handle, and the workman does not require an assistant to put the stone in motion as when a winch-handle is used. The employment of the treadle is even now far from being so universal as it deserves to be, notwithstanding that it was known and published so long as three centuries back.

7.—Grinding Lathes, or small Grindstones driven by Foot-wheels and Treadles.—Stones not exceeding a foot to a foot and a half diameter, do not present sufficient momentum to admit of their being driven as in the last example, unless a foot-wheel of moderate weight is added to the lower part of the frame, the upper part of which then carries the grindstone spindle fitted with a pulley, so that a leather strap or a catgut band may communicate the motion of the foot-wheel to the spindle in a manner analogous to

that employed in foot-lathes; whence this arrangement has been called the GRINDING LATHE. The same frame or lathe is commonly fitted with buff and brush wheels, and is then much used by cutlers for many parts of their works that require but secondary care; this apparatus is also used by many of the workers in horn, tortoiseshell, ivory and other materials; but cutlers always polish the blades and superior parts of cutlery, upon the apparatus next to be described.

8.—CUTLERS' GRINDSTONE DRIVEN BY THE FLY WHEEL.—Cutlers' grindstones range from about 6 to 24 inches diameter, and are fixed upon square iron spindles from 12 to 30 inches long, terminating in steel pointed centers; the stone is wedged fast near the right hand extremity of the spindle, and near the left is fixed the pulley for a leather strap which usually measures from 1 to 2 inches wide. The strap commonly proceeds from a hand-wheel of about 5 or 6 feet diameter, turned by a labourer who is situated at the back of the grinder, and the entire arrangement, from the length of space occupied, is familiarly termed *the long wheel*, but in large establishments the stones are generally driven by steam or other power.

The framework for supporting the grindstone spindle usually consists of two long pieces or sleepers that lie on the ground and are united at their extremities, they have near the one end two perpendicular posts or standards, at the upper parts of which are placed the hollow centers for the spindle to run in; lignum vitæ is the material preferred for the centers, horn is sometimes used, and in a few cases screws with steel centers are employed. The center block on the left hand for the centers near the leather strap is usually pierced with three or four holes in a horizontal line, for the convenience of making the strap more or less tight, and also for adapting it to pulleys differing somewhat in diameter, without shifting the wheel. Sometimes the post for the center on the right hand, is fitted between two transverse pieces or bearers and secured by a wedge, like the popit heads of early turning lathes, in order to serve for spindles of various lengths; because the same frame-work is commonly used by the cutler not only for grindstones, but also for various laps, buffs and glaze wheels.

The Sheffield grinders generally employ ash for the center blocks and wedges for grindstone spindles, and they mostly run all their stones and glazers in one set of holes and adjust the length of the straps for various sized pulleys by using short pieces of strap of different lengths, which they apply by means of round buckles.

Between the standards and below the stone lies a long narrow water trough of wood lined with lead or of cast iron, sometimes called the "*dog-pan*," but which should never contain enough water to reach the stone, as the centrifugal motion would splash the water about in an inconvenient degree; the water is therefore at intervals thrown on from a pail with the hand, or is allowed to flow from a thread-like jet on the *side* of the stone very near its periphery. The workman is seated astride a board called the *horse*, which rests behind on the bearers or sleepers of the frame, and in front is propped up by a transverse bar of wood, which is shifted to or from the stone, to adjust

the front end of the horse to a convenient height, dependent on the diameter of the grindstone. The edge of the horse near the stone is commonly shod with iron that it may be used for supporting the turning tool employed in *turning up* the grindstone, and the horse has usually a piece of leather or sacking or a sloping board to keep off the wet thrown up by the centrifugal motion. The framework is sometimes furnished with a splash-board, which is placed almost perpendicularly on the other end of the trough, and projects above the top of the stone, so as to catch most of the water that flies off and reconduct it to the trough; but the splash board is not always added.

9.—The Position of the Grinder when at Work is highly favourable, he is seated before and rather above the stone with his feet resting upon the ground or other firm support, and in the act of grinding and polishing delicate works they are held by both extremities in the two hands whilst the elbows rest upon the knees, so that the grinder can thus keep his person very steady and is enabled to feel with great delicacy and exactness the position of the work upon the stones or polishers. But in polishing the handles, springs, middle parts of pocket knives, and other small pieces the cutler frequently employs the grinding lathe just described in article 7.

10.—Large Grindstones for Heavy Edge Tools, Saws, Gun Barrels, &c.—Manufacturers in these branches use much heavier grindstones than cutlers, and mount them somewhat differently. Stones larger than 3 feet diameter and 4 or 5 inches thick, and those extending to the dimensions of 8 or 10 feet diameter, and 12 to 16 inches thick, are commonly wedged upon square spindles having *cylindrical necks*, that run on bearings either of hardwood or metal, and the pulley is generally placed at the extremity of the spindle and outside the one bearing, so that it may be changed agreeably to the decreasing diameter of the stone without the trouble of lifting the latter from its bearings, which is not commonly done until it is worn too small for its particular use. A deep groove is then turned in the periphery of the stone, which, after removal from the spindle, is split in two by chisels and iron wedges to serve for smaller works.

The arrangements of the trough, horse and splash-board for large grindstones differ principally in size alone from the preceding; frequently however the axis of the stone is level with the ground, and the bearings are fixed on two sleepers between which the earth is simply excavated to form the trough, indeed, the grinder's tools, although so effective, are generally of the most simple and inexpensive character.

11.—Large Stones are always driven by Power, a drum of three to five feet diameter commonly extends across the grinder's shop, and the stones are arranged in a line on each side of the same. The *surface velocity* of the drum is commonly about 200 feet in a minute, and the diameter of the pulley being about one-third that of the stone, the surface velocity of the latter is from about 500 to 600 feet a minute. With large stones this speed occasions so much momentum as to endanger their being split if there should be the smallest flaw in the stone, or from neglect it acquires a *heavy side*, from being allowed to wear out of the true concentric figure. The centrifugal

force then sometimes breaks the stone, and drives the huge fragments with frightful violence through the roof or walls of the building, to the occasional destruction of human life.

12.—FLANGES AND RINGS TO PREVENT STONES FROM BREAKING.—The liability of grindstones to be broken by excessive centrifugal force is materially lessened if not altogether averted, when four or six holes are made through the stone and iron plates or rings covering about one-third to one-half of the diameter are bolted on each side, sacking, felt, pitch or some soft materials being interposed, so that the stone and two side plates when bolted together may form a compact solid mass. Flanges are also used as well as rings, but neither of them so generally as they ought to be, especially when from cupidity it is attempted to drive the stone as fast as it will bear with *hoped for* safety, in order to hurry through as much work as possible. In the new and unprotected stone, there is a considerable body of the material or length of radius to withstand fracture, but when the stone is reduced by wear to *half* its primary diameter, and its axial speed is *doubled* to maintain its original *surface velocity*, the risk is much increased because there is then so much less bulk in the stone to resist accidental fracture.

13.—ENGINEERS' TOOL GRINDSTONES or those employed for keeping in order their working tools; vary from two to five feet diameter and four to eight inches thick, and the structure of the framing is usually in metal. The trough is made either entirely of cast iron, or with cast iron sides united with a wide strip of boiler plate rivetted to each; and usually has feet to support the axis at two to two and a half feet from the ground to suit the erect position of the workman, who holds the tool securely on a horizontal iron bar that is fixed near the stone and at a convenient height by means of pedestals secured to the frame, which arrangement gives the choice of position in the rest or bar. The axis is cylindrical throughout, and the stone is fixed on its central part, as will be explained: the spindle lies in two plummer blocks or brasses which are fixed on the edges of the trough, and one end of the spindle overhangs the same to receive the strap pulley by which the stone is driven from the main shaft running through the building. There is also provision for changing the diameter of the pulley on the main shaft or on the spindle, to increase the velocity of the stone as it becomes reduced in diameter; but unlike the generality of machines in the engineers' shops, the grindstone does not require fast and loose pulleys to connect or disconnect it with the power, as from its frequent use it is kept continually running when the engine is at work.

Engineers mostly fix the stone between cast-iron flanges or plates, the one keyed on the spindle against a shoulder, the other forced up by a screwed nut or key passing through a diametrical mortise in the spindle. An excellent mode of hanging the grindstone is to fit a square piece of wood into the eye of the stone, bored to fit the spindle, and afterwards having smoothed the central parts of the sides of the stone, to interpose two discs of soft pine wood between the cast-iron flanges and the stone,—the wood adapts itself to the trifling irregularities of both parts, and serves as a somewhat elastic cushion to ensure contact and

consequently a firmer grasp on the stone, to the extent of about one-fourth of its diameter, to which the flanges extend;—by these precautions accidents rarely occur. Engineers sometimes use stones of the before mentioned diameter of 8 or 10 feet for brightening the coarser parts of machinery, and such large stones are mounted nearly the same as those just described, but nearer to the ground.

With a view to maintain engineers' grindstones cylindrical and in good condition throughout their service, two grindstones of similar size are sometimes mounted in one frame, their axes parallel and with a power of adjustment towards one another; so that the two stones may run at different surface velocities in moderately forcible contact to mutually abrade and correct the wear upon their edges. Both are covered and enclosed by a cast iron case or hood fixed to the oblong trough beneath, to catch the water and detritus thrown up between the stones; and the hood has an aperture at either end to expose about a quadrant of each stone at the part used, where also they receive the water from a reservoir on the top of the hood. One side only of each stone, therefore, can be used, and it is perhaps questionable whether the results sought are worth the additional wear of the stones, and increased space and power for driving.

14.—Turning up Grindstones.—When the stone is wedged truly on its axis, it is turned on the cylindrical edge or *face* and part way down each side. This is commonly done with a rod of iron or steel drawn down at the end to about $\frac{3}{16}$ths to $\frac{3}{8}$ths of an inch square with the stone dry. The tool is not held radially but pointed downwards, at an angle of about 20 degrees, and is continually rolled over and over to present a new angle, which in its turn is rapidly worn away. The process is nevertheless much quicker than might be supposed.

In turning small grindstones driven by the long wheel, the stone is moved the reverse way, and more slowly than in grinding, so that the horse may be used for supporting the turning tool. In turning large grindstones driven by power, in which case the motion cannot be so readily reversed nor slackened, the workman goes to the back of the stone and supports the tool upon a wooden or iron bar placed across the water trough, and employs a larger pulley than for grinding. Sometimes a cross strap is allowed to run upon the edge of the stone itself, to reverse and reduce the speed of the stone when it is turned after having been mounted.

Grindstones of all dimensions are more rapidly turned true with the revolving disc tools patented by Mr. Brunton; which are either circular pieces of unhardened sheet steel, dished or struck up into shallow truncated cones from 3 to 4 inches diameter, or for the largest stones, flat chilled cast iron discs with angular edges about 5 to 8 inches diameter. They are mounted to revolve freely upon the end of a steel spindle, and rotate by surface contact alone as they are traversed across the face of the revolving stone, held in a sliderest temporarily attached to its frame. One side of the periphery of the revolving disc tool alone touches the stone; and the tool is phenomenally permanent, due to the circumstance that by its continually turning on its axis no point on

the edge, as it does its work, stays an instant in contact to receive wear or damage from the stone; which latter is reduced to a clean true face with an economy of time almost as remarkable. The stone can also be turned wet, which avoids the dust that accompanies the older method. The details of these tools are described, Chapter II., section 1, together with some other varieties of disc tools used for the same purpose.

Large stones are seldom turned up, except when they are first set to work, but are retained of a cylindrical or slightly convex figure, almost exclusively by the following process:—

15.—Hacking Grindstones.—At intervals during the time a large grindstone is in regular work, the strap is flung off and the stone is retarded by still applying to its surface the article being ground; but before the stone comes to rest, the high places are marked at six or more parts of its width, by holding a piece of chalk or charcoal steadily upon the horse, and gradually approaching it so as to mark the more prominent parts. When the stone has stopped, the grinder hacks or notches the high places denoted by the marks, by means of a tool called a "*hack hammer*," which is like a small adze of 2 or 3 lbs. weight, but longer and more curved in the blade and with a very short handle. The grinder cuts with the hack hammer shallow oblique furrows about one inch asunder and crossing each other, producing a chequered surface. When the stone is again used the greatest wear occurs at these roughened places, and by a continual recurrence to the *dressing* the circularity of the stone is sufficiently well preserved, with but little interruption to the work. It is very impolitic to defer the dressing too long, for fear of giving the stone a *heavy side*, and risking its safety.

16.—Straggling or Ragging.—This process is principally adopted on fine and smooth grindstones into the surfaces of which particles of iron or steel have become embedded, which then greatly impede the action of the stone. In *straggling*, or *ragging*, the stone is kept running as usual whilst a piece of soft iron about a quarter or half an inch square, held upon the horse like the turning tool, is wriggled against the edge of the stone by a motion of the wrist, as in using a brad-awl, the iron is applied all over the surface, and lastly the edge of the bar is wriggled obliquely upon the top of the stone. This process also assists in correcting small inequalities in the figure of the stone.

17.—Turning and Roving Smooth Grindstones.—A different and perhaps more general mode of keeping the stone in order, especially when it is driven by the hand wheel, is followed by other workmen.

The motion of the stone is reversed, and the edge is turned with a bent tool, usually made out of an old file, by forging the end taper and to a thin wide chisel edge, and about one inch of the tool is then turned up nearly at right angles to the length of the file. This tool is used as a hooked turning tool upon the horse and it scrapes the surface tolerably true and smooth. Afterwards whilst the stone is at work its edge is cleared with the roving plate, a piece of either iron or steel plate just like a joiner's scraper, held upon the top of the stone not quite perpendicularly but meeting the stone at

a small angle. From its unstable position the roving plate chatters and jumps, and appears to fill the stone with minute furrows from dislodging some of the particles from its gritty surface. This mode also gives the stone a tooth and, as well as the last method, serves to clear the stone from the thick dirty water or slush that otherwise fills its grain and considerably retards its action, frequently also the grinder throws a small handful of water on the stone, and applies his open hand very gently upon the same, in order to wash off the loose muddy coating it acquires whilst in use.

18.—General Remarks on Using Grindstones.—In order to avoid the wasteful destruction of the stones they should be exposed to as equal circumstances as possible; thus they should in the first instance be selected free from hard veins that impede, or flaws that accelerate the wear at the respective parts. The object ground should be continually traversed backwards and forwards to use the stone alike all over, the stones should not be allowed to remain long out of condition, as they get rapidly worse, neither should they ever remain partially immersed in the water in the trough, which would soften those parts and expose them to more rapid wear than the remainder.

In almost every case the grindstone is made to revolve *away* from the workman, so that should the work slip from his grasp it may be carried away from his person and not against him. But this direction of motion leaves a wiry film on tools with thin cutting edges, and this the regular grinder avoids, by occasionally holding the tool *back-handed*, or with the edge towards his person. Many of the tools used in turning metal do not require to be sharpened on the oilstone, and to avoid the wiry film, such tools are usually ground with the stone running towards the workman.

The Bilston grindstone has the preference for small tools from the comparative smoothness of its grain, and occasionally, a coarse and a fine stone are fixed on the same spindle; and when the shop grindstone is driven by power, the workman goes to the front or back of the stone accordingly as the motion is best suited to his immediate want.

19.—General Remarks on Grinding Various Kinds of Tools.—The general position of the grinder described under article 9, serves for grinding all ordinary tools, such as chisels, axes, and many others of ordinary kinds, which are simply held to the stone by the hands, and receive the pressure of the arms and upper part of the person.

20.—*Massive works*, such as anvils, are suspended loosely by a chain, the man has then only to guide them, and their own weight supplies the pressure.

21.—*Large heavy plates*, such as the bright cast-iron fronts of stoves, are allowed to rest in an oblique position, jointly upon the surface of the horse and the stone, the grinder slides them about, to expose all parts of the surface to equal action, and often bears on them with his knees to increase the pressure.

22.—*Saws* are too thin and elastic to be thus treated, and such flexible objects are applied on a flat board to give them support, the man leans upon the board with his whole weight and moves them up and down at an inclination of about 45° to grind every part successively and equally.

23.—*The blades of table knives* before being handled are ground on the side of a stick, about $2\frac{1}{2}$ by $1\frac{1}{2}$ inches and 2 feet long with a staple under which the shank of the blade is placed, the stick is rounded at the ends to serve for the two hands, and the workman also sometimes applies his knees to the central part, and the effect of the stone is then very rapidly felt on the blade.

24.—*Small works that are ground lengthways,* are sometimes nipped between the horse and the stone, an enormous pressure may be then given much less laboriously than by the arms, this is often done in grinding the surface of files preparatory to their being cut with teeth, and in *stripping* the teeth from old ones, prior to re-cutting them; but this practice throws a great pressure on the stone, sometimes enough to check the speed of the steam engine.

25.—*Small works are in many cases difficult to be held unassistedly,* because of the risk of grinding through the skin of the fingers, or of burning them from the heat of the work, a small pointed stick is frequently used to press the work on the stone, and in some cases a small square piece of thick leather or felt, called a *patch,* is similarly employed. Sometimes also small tools are temporarily fixed by their tangs in a wooden handle to facilitate their presentation to the stone; the handle is called a "*haftpipe*" and is commonly a short piece of hazel rod. But the more usual course at Sheffield is to employ a pair of tongs or pliers, the reins of which do not cross as pliers and scissors generally, but consist simply of two rods of iron retained by a link across their middle. The work is fixed by being inserted between the rods at the one end, and a wooden wedge driven in between the opposite extremities, binds the whole together very securely. The sliding tongs, Fig. 861, page 862, Vol. II., are also used occasionally.

26.—Adaptation of Grindstones to the Forms of Works.—*Convex* works may of course be ground upon the cylindrical edge of the grindstone, as by rolling the work about every part may be brought into contact with the stone, in the same manner that round or convex works may be filed with a flat file; but in grinding *concave* works, it is needful that the stone if not altogether a counterpart of the work, should be sufficiently modified in form to penetrate to the bottom of the hollow. Thus in grinding a pruning bill, the hook of which is of small radius, it is indispensable that one edge of the stone should be rounded to the fourth of a circle; in grinding that part of a table knife where the blade is united to the shoulder, a similar curvature in the stone is also required. In grinding hollow or fluted works such as the concave parts of gouges, it is necessary to turn the grindstone to the exact counterpart form, or into beads of different widths and sweeps, and various other examples might be cited.

In order to reach within that keen edge in the blade of a penknife which unites the square shank for the joint to the remainder of the blade, (which angle is technically called the *chorl,*) the edge of the stone is kept remarkably keen and sharp, this is assisted by waxing the side of the dry grindstone close to the edge, which tends to prevent the same from crumbling away, and also prevents the stone cutting into the shoulders of the blade.

27.—Wet and Dry Stones.—Grindstones are generally used with water, as in the humid state they cut more quickly, because the wet prevents the grain of the stone being choked with particles of metal, but when the stone is used dry, although it cuts somewhat more slowly, it leaves a smoother grain upon the work and on this account the dry stone is always resorted to by fork-grinders and needle pointers.

28.—*The dry stone* is somewhat used also by most grinders, but only for a small part of their work, as when vigorously applied it gives rise to so much friction that it frequently heats the work to a blue or almost to a red-heat and would destroy the temper of the tools, its use is therefore nearly restricted to the roughing-out of tools, *before* they are hardened, an operation called "*scorching*"; at this early stage of the manufacture of tools they receive no injury from the great heat sometimes thus given them.

29.—*Hardened and tempered blades* that have been ground on the wet stone, are often smoothed on a dry Bilston stone, in order to leave less work to be accomplished in the next stage of manufacture by the metal lap with fine emery; but the practised cutler then applies the dry stone so moderately as not to reduce the temper of the blades, but only to smooth them.

30.—Danger of Using Dry Stones.—A still worse and more fatal mischief than spoiling the work attends the continual practice of dry grinding, as the fine particles of stone and steel that are given off raise clouds of dust which are inhaled by the workmen, and so commonly does this contaminated atmosphere induce pulmonary complaints, that it is considered rare for a needle or fork grinder to live beyond the age of twenty-five or thirty, at which period they generally become afflicted with asthma and premature decay.

31.—To avert this calamity the late Mr. Abraham of Sheffield, and several others have invented magnetic guards which were placed close to the grindstone, and sometimes also around the mouth and nostrils of the individual. The magnet attracted the particles of steel and together with them drew the greater part of the stone dust, but the men were too heedless to avail themselves of this philanthropic invention, notwithstanding its complete success.

32.—A contrivance now employed was also due to Mr. Abraham, the stone is enclosed in a wooden case that only exposes a part of its edge, and from the box a horizontal tube also of wood, proceeds as a tangent from the upper surface of the stone to the external atmosphere. The current of air generated by the motion of the stone makes its escape through the tube, and carries with it nearly the whole of the dust arising from the process; sometimes the tube alone is retained. But even this contrivance, (which may be viewed as comparable with the revolving fan now used in blowing furnaces,) although so much less elaborate than the magnetic guards, yet nearly as effective, is also for the most part neglected, owing to the unpardonable heedlessness of the workmen themselves. The revolving fan is more frequently used with emery wheel grinders.

SECTION B.—WHEELS OF FACTITIOUS STONE AND OF EMERY, OR COMPOSITION WHEELS.

33.—ARTIFICIAL GRINDSTONES.—These are made of various widths and from about 2 to 6 feet diameter, by an ingenious chemical and mechanical process patented by Mr. F. Ransome, 1867. Dried Maidstone sand, first washed to cleanse it from impurities, is very thoroughly mixed in the proportion of about 20 parts of sand to one part of silicate of soda, with one part of powdered chalk added, under a pair of edge runners. The result which resembles coarse moist sugar and has a small cohesion when pressed between the hands, is rammed into open moulds in the same manner as described for Emery wheels, *see* EMERY, article 12. A solution of chloride of calcium is then flooded on the surface and sucked through the sand and the perforated bottom of the mould by an air pump. This sufficiently hardens and compacts the artificial stone at this stage, to enable it to bear handling to remove it from the mould to place it in a bath of chloride of calcium in which it is boiled from 12 to 36 hours. A dual decomposition takes place in the chemical constituents, the chloride of calcium and the silicate of sodium combine into chloride of sodium and silicate of calcium, or lime. The last which is insoluble cements the particles of sand into a solid mass, and the chloride of sodium, common salt, partly effloresces; the chloride of sodium is useless and inconvenient in grinding, but it is soluble, and its entire removal is the last process, effected by long washing under a plentiful head of water; sometimes, by placing the stones for about 3 weeks under an artificial rain pouring upon them from tanks with perforated bottoms.

Ornamental stone of remarkable permanence, for architectural purposes, has also been moulded of the same materials and in the same manner, except that the final washing is exchanged for burning to a white heat. This burnt stone is unsuitable for grindstones.

Ransome's artificial grindstones closely resemble the natural Newcastle grindstones both in cut and appearance. To test their quality the writer experimented with one of about 5 feet diameter and 8 inches wide, and to avoid possible prejudice, had it mounted in the grinding shop without naming its origin. This specimen compared favourably in cut and wear with the natural stone it had replaced; the same grinder used it continuously for some months, until it became too far reduced in diameter for economical use in grinding heavy edge tools to shape from the forgings; when then informed, the workman admitted he had not detected it as other than a rather harsh cutting natural gritstone. The same stone was then mounted in the engineer's shop for grinding lathe and planing machine tools, here it was so esteemed that it was retained until reduced far below the usual minimum diameter for such purpose; and after this, it was returned to the grindery and used as a small stone until completely worn away.

34.—CORUNDUM WHEELS, are made of corundum cemented into a mass by means of shell lac—*see* CORUNDUM, article 2—and more frequently of corundum, lime, Portland cement and silicate of soda, after the same manner as emery

stone wheels,—*see* EMERY, article 12. They range from about three quarters of an inch to about 5 inches in diameter, and from very thin to about half an inch thick, with knife edge, elliptical, round and cylindrical edges, and are of two or three degrees of fineness. The smaller sizes are extensively used by mechanical dentists upon the mineral or porcelain teeth and their gold and vulcanite mountings; driven in their small lathes or, very frequently, by miniature Stowe Flexible Shafts, the varieties of which are described in Chapter IV The round edged corundum wheels are useful in grinding the concave edged tools and cutters used in ornamental turning.

35.—BARCLAY'S ARTIFICIAL EMERY STONES.—The manufacture of these grinding and polishing wheels, is fully described under the head EMERY, article 11: in most respects they are superior to the corundum wheels of the Asiatics described under the head CORUNDUM. They were made of various degrees of coarseness and rapidity of cut, but are now superseded by the Emery wheels referred to in the following article.

36.—EMERY WHEELS, generally in use in engineers' workshops and known under various brands or names, are all similar in their composition, which has been described under the head of EMERY, article 12. They range from a fine to a very coarse grain according to that of the emery used, one size of which alone is supposed to be employed in the composition of any one wheel; but frequently a proportion of a somewhat finer size is mixed with the main bulk of the coarse emery, not for its cutting properties, but to aid in filling the interstices and binding together the coarser grains. Those mounted on spindles, range in size from 2 to 36 inches and sometimes to 48 inches in diameter, and are from one eighth of an inch to 10 or 12 inches thick; they are employed for many of the purposes of the ordinary grindstone, but, perhaps, more extensively in special machines, some of which are described in Chapters III. and IV., in these machines the revolving emery wheel replaces the file, turning and planing tools for the production of plane surfaces, cylinders and solid forms and for grooving and fluting, with remarkable economy. It is generally considered that the harder the metal, from brass to steel, operated upon, the harder and closer grained should be the emery wheel employed.

Properly compounded the emery wheel abrades or "cuts" freely and is very permanent; it is used both wet and dry under the same general conditions that apply to gritstones. Whilst in its plastic condition the material may be moulded into any required shape, cylinders, discs, crown wheels or hollow cylinders, which grind by their annular faces, and keystone shaped pieces are employed in different grinding machines. The greater proportion of the wheels are used as moulded but their edges or faces may afterwards be readily turned with a carbonate diamond tool,—*see* ante,—to convex or moulded profiles for hollow or straight grinding, for which class of work the emery wheel is more durable than the natural gritstone.

A different variety is used for polishers or glazing wheels; in these, other materials, gums, powdered cork, caoutchouc, etc. compact the mass and also serve to clog or impede the activity of the very fine emery of which they are made, the effect desired.

37.—Opticians *sometimes employ fine crocus made into a solid body* with wax, and moulded or turned into form, see the article on Lenses and Specula, Chap. VIII. The wax polisher is generally used with water, which greatly prevents the destruction of its surface and also assists in carrying off those particles of glass or metal which do not become embedded in the polisher. The introduction of this composition is ascribed to the late Mr. Varley.

38.—Crocus, mixed with powdered chalk and melted glue, constituted the composition employed by the late Mr. Bass in the formation of little wheels, employed by him in sharpening the long slender straight blades of his cork cutting machine. In cutting each cork the knife sweeps by against a square piece of cork, which, during the time makes one revolution, and the four angles are removed in one piece. The knife in proceeding to and fro is rubbed on its upper side by three of the crocus wheels; which revolve slowly against it with slight pressure, and the lower side of the knife rubs against two or three hard steel rings, which act as burnishers and keep up the fine wiry edge required in cutting cork.

In hand cutting the operator rotates the squared pieces of cork against a stop on the bench, held by their ends between the finger and thumb, and he keeps his knife in condition by passing its long straight edge once to and fro along the surface of a narrow flat piece of gritstone, used dry, fixed on his bench beside him, every time simultaneously with his picking up a fresh piece of cork; and this necessary perpetual sharpening has to be provided for in all cork cutting machines by arrangements analogous to that mentioned above.

Section C.—Wheels of Metal, or Metallic Laps.

39.—Metal Wheels or Laps, made of nearly every metal and alloy in common use, have been more or less employed in the mechanical arts as vehicles for the application of most of the polishing powders, but of all laps, notwithstanding their variety, those of lead slightly alloyed and supplied with powdered emery, render the most conspicuous service. Generally the plane or flat surface of the lap is employed, at other times the cylindrical edge, as by cutlers, but the portion actually used is in either case called the *face* of the lap.

40.—Lapidaries, Marble Workers, sometimes also the mechanicians and others, place the spindle vertically, so that the lap revolves in a horizontal plane, in which case the lower end of the spindle is supported in a center fixed to the cross rail of the wood frame or bench, the upper in a bracket or overhanging arm extending from the platform, and beneath the latter is placed the pulley by which the spindle is driven. In some cases the upper center is dispensed with, and the spindle works in a metal collar just beneath the lap—after the manner of a lathe, if we conceive the mandrel to be placed perpendicularly.

The lap in all these cases revolves within a shallow trough, extended two to six inches above the lap, in order to catch the emery and water that are thrown off. The emery is usually applied dry, the lap having been previously moistened with a small brush dipped in water or with a mop made by twisting a wire around a few rags, the wire serving also as the handle the

dry emery powder then readily adheres to the lap and less water is required than if the emery and water were previously mixed. In some cases the lap is screwed upon the mandrel of an ordinary turning lathe like a chuck, but this is hazardous, lest the emery should find its way to the collar of the lathe mandrel.

41.—Cutlers' Laps are fixed on spindles placed horizontally, in precisely the same form that serves for their grindstone and other apparatus. Cutlers' laps measure from about 4 to 20 inches in diameter, the best razors being smoothed on laps of 4 to 6 inches diameter, and commoner razors on those from 10 to 12 inches, which act the more expeditiously but leave a thicker edge.

42.—Differences of Construction in Laps.—The lap is in some cases a thin disc of metal fixed by means of a screwed nut against a shoulder on the spindle, but it is better with lead laps to employ an iron plate cast full of holes to support the softer metal. The casting mould may in this case be either an iron disc with a central screw to fix the iron center plate at the time of pouring, or the mould may be made of sand and in halves after the usual manner of the foundry. In either case the iron plate should be made as hot as the fluid metal, which by entering the holes becomes firmly united to the iron especially if the holes are largest or countersunk on the reverse side or that away from the lead.

43.—Cutlers' Narrow Cylindrical Laps are sometimes similarly cast upon the edges of cast-iron wheels or discs, but it is far more usual to make a wooden center on account of its lightness. In order that the wood center may not contract nor lose its circular form, it is made in four quarters or of more pieces, with the grain pointing to the center; the pieces are united by two circular discs of wood or metal, nailed to the sides, after this the edge is turned to the required width and cylindrical, with a groove in the center and a chamfer on each edge, to retain the lead.

The writer is in the habit of casting similar laps, of the materials mentioned in the next paragraph, up to about 2 feet diameter, upon the peripheries of the ordinary toothed wheels of slide lathes. Such wheels more or less damaged in their teeth from accidents and thrown aside as old iron are readily obtained to serve this purpose; their arms give them the desired light weight, and the teeth securely retain the metal cast upon and around them. The teeth of the wheels should be first thoroughly cleansed from dirt and oil and brightened by brushing out with sand or emery before they are placed in the open mould; which latter is constructed on a piece of flat sheet iron, with a central pin to fit the bored center of the wheel, and a wide ring of loam, swept out circular from the pin as its center. The inner edge of the rim of the wheel should also be luted up with loam, and the surface of the mould carefully levelled before pouring in the lead.

The mould for casting laps generally used is an old grindstone in the center of which is placed the wooden disc, and around the latter is built up at the distance of 1 or 2 inches a border of soft clay. The metal, usually 1 part tin and 4 or 5 parts lead, (the lining of tea chests being preferred, on account

of the tin with which it is alloyed and soldered, is then melted and poured in, but the heat should be barely such as to scorch white paper. The lap when cold is fixed on the spindle, and its edge is turned true, the horse being used as the support for the turning tool.

44.—THE CYLINDRICAL EDGE OF THE LAP, which alone the cutler employs, is called the *face*, and the dressing or coating of emery, which is never used by cutlers with water, is called the *head*, terms applied in common to his other wheels. In order to make the smooth metal retain the fine emery, it is *scored* or scratched with a pointed knife, by which two series of slight oblique furrows are scored in the face of the lap, to produce a faintly but coarsely checkered surface.

45.—IN LAPPING RAZORS AND LARGE ARTICLES, fine emery and oil are mixed up in a cup, a small quantity is spread on with the thumb whilst the lap is nearly at rest, the emery is then pressed in the lap with a spoiled razor blade, or a short bar of razor steel, that from which the blades are forged, whilst the lap is in motion, and when the lap is charged the work is drawn steadily across from end to end and entirely off the lap, to reduce it to an uniform surface.

After having preparatively lapped about one dozen of razor blades on both sides, which is called *the first course*, the process is repeated with finer emery, or else "*to fine the lap*," the head is rubbed off with a piece of felt or with thick woollen cloth, and the surface of the metal is rendered as fine as possible with a smooth piece of flint or with a steel blade; and the lapping is completed in the last course on the nearly naked lap, a stick of charcoal being commonly used to still more deaden the emery before the flint is applied, and the charcoal moreover gives a black polish that could not otherwise be left from the lap.

46.—IN LAPPING PENKNIVES AND SMALL ARTICLES, it is more usual to charge the wheel whilst it is at rest, by rubbing on it a lump of emery cake, made of emery compounded with suet chopped fine and rendered down and mixed with a very little wax; sometimes the dressing is rubbed in with the agate or bouldering stone, and as before explained, to fine the lap, at the conclusion the head is rubbed off and it is smoothed with the agate.

When the lap is coarse and the work is pressed heavily it produces a white colour on steel, and when the lap is fine and the work is pressed lightly, and gradually drawn from the one end to the other it gives a black polish—to attain this end the emery is worn down fine with the work, and afterwards with the bouldering stone, and the effect of the emery is still more deadened by putting a little beeswax on the face of the lap, the smoothness of which is tried with the finger before applying the work.

47.—COMPARATIVE DURABILITY OF LAPS.—The metal wheels and grinding tools are from several reasons highly advantageous; they admit of being fashioned with more exactness, and they longer retain that exactness than the natural stones and the compositions previously referred to. For instance with grit stones disintegration is constantly and rapidly going on, as in the course of work the particles of the stone are rubbed down and torn out, so that the

abrading surface is incessantly changing by the gradual exposure of the part of the grindstone previously beneath. Much care is required to keep the edge of the stone circular and of the precise form required. With the cement wheels, this progressive change as constantly occurs, although more slowly from the abrading and structural materials being mingled.

48.—On the Action and Durability of Laps.—Metal laps are under very different circumstances from grindstones or cement wheels, as the metal constituting the lap has no cutting power in itself, but only derives it from the particles of emery which become embedded in its surface and act as the teeth of a file. Other particles of the emery lie continually between the metal lap and the article to be ground, and separate the two; these grains have a partially rolling motion and, in all probability, have a tendency to grind both the work and the lap also. When the emery is crushed very fine, or has wasted, so that the lap and work come nearly in contact, the abrasion becomes so much reduced that fresh emery is generally thrown on to restore the action, and this again separates the lap and work, which therefore rarely come into absolute contact. It must not be supposed, however, that although the metal is generally more cohesive than stone or cement, it is not at all worn away, as the metal laps are likewise depreciated in form, but in a much slower degree than the cement wheels or natural stones.

49.—Metals employed for Laps and their respective Purposes.—In the selection of the metals for laps there is much of prejudice, speaking generally it may be said the softer the metals the more readily do they retain the grinding powders, but the sooner are they worn out of form. The more usual metals for laps and their purposes are as follows :—

Brass is used by

Opticians, with fine emery and water for smoothing lenses and specula.

Cast-iron is used by

Glass-grinders, with coarse sand for roughing;

Opticians, with sand or emery for rough grinding;

Engineers and machinists, with emery and water for general purposes, in metallic construction;

Diamond polishers, for polishing the facets of diamonds for jewellery; the iron laps or *skives* charged with diamond powder.

Copper is used by

Engineers and machinists, with emery and water for general purposes in metallic construction. Copper is considered to retain the emery remarkably well;

Lapidaries, with flour emery for grinding small and hard gems, and for cutting facets;

Glass grinders, with emery for fitting stoppers into bottles;

Glass engravers, with emery for their small discs and tools.

Lead, generally alloyed, is used by

Engineers and machinists, with emery and water, for metallic lap construction generally;

Cutlers, with emery and oil, for fine grinding or perfecting the forms of cutlery prior to polishing the pieces;

Lapidaries, with emery, first coarse and then fine, for grinding and smoothing most stones, except some few of the hardest, which require copper;

Lapidaries, with rottenstone and water, for polishing most of the stones, except a few of the hardest, which require hard pewter or copper;

Lead, mixed with a variable quantity of antimony or alloy, like type metal, is much used by engineers and mechanicians for laps.

Pewter is used by

Gold cutters, for cutting and faceting gold and silver, to which a most splendid lustre is given by means of crocus, which is generally rubbed into the lap with the burnisher;

Watchmakers, with crocus or red stuff as above, for polishing some of their brass and steel works;

Lapidaries, with emery for fine grinding, and also with rottenstone for polishing,—pewter being selected for those small and hard stones, for which lead is too yielding.

All these artizans select in preference the metal of old pewter plates, which consisted of pure tin with a minute addition of copper. Some of the modern pewters appear to be tin and lead in nearly equal parts, and are much the same when used for laps, as lead hardened with a little antimony, which is much less expensive. *See* articles PEWTER, Vol. I., page 284, and LEAD, page 277 of the same volume.

Tin may be considered as being applicable to all the purposes of the genuine old plate pewter, which is now difficult to be met with.

Zinc, alloyed with tin, which is much harder than tin or pewter, is said to be employed by the Geneva jewellers in lapping gold and silver works.

SECTION D.—WHEELS OF WOOD, OR GLAZE WHEELS.

50.—LAPIDARIES employ wooden wheels in smoothing soft and rounded stones. The wheels consist usually of beech, birchwood, or mahogany, cut out plankways, fixed on the spindle and turned flat. The wood wheels are fed with flour emery and water, as described under the article in this Catalogue on ALABASTER.

51.—GLASS CUTTERS employ the edges of similar wheels with pumice-stone and water for smoothing, and with putty and water for polishing; the edge of the wheel is turned flat, angular or circular, according to the fashion of the work. Willow, poplar or alder, which are amongst the softest of our woods, are much used for the glass cutters' wheels: their face wheels, which are far less common, are mostly thick transverse sections of the tree, and consequently the grain is then upright at every part and both more equable and durable. Cork sometimes replaces willow wood wheels with putty powder and water for polishing; they are run rather faster and are said to give a better polish. The wheels are built of thin segments cemented to wood discs or held between discs

of iron, tin or wood screwed through from side to side; the segments cut from slabs of cork previously flattened by pressure between heated iron plates.

52.—Cutlers use wood wheels under the name of glazers; these should be constructed of two layers, each consisting of 6, 8 or more pieces with the grain radial, so that the periphery may be entirely formed of the end grain of the wood; walnut, oak, crab-tree, birch and mahogany are severally used, but the latter is on the whole the best. The cutlers' wood or glaze wheels are mostly fed with emery cake, already described, which is applied whilst the wheel slowly revolves.

The edges of glazers are occasionally scored with a pointed knife, to enable the emery cake to penetrate, and for fine work, they are also bouldered down with a flint, or other hard and smooth stone, and waxed to render the edge smooth, just in the manner recently explained in reference to cutlers' laps. Sometimes a wood wheel fed with emery and oil is first used, and afterwards a wood wheel with emery and wax.

Section E.—Wheels of Leather, or Buff Wheels, Glazers and Polishers.

53.—This title includes three different kinds of apparatus, all of which have wooden centers covered with leather and are thence sometimes indiscriminately called buff wheels, but they are distinguished into three kinds as above by practical men, thus:

First. Buff wheels which are covered with thick soft leather, sometimes half an inch thick, the bull neck being commonly employed. In the metropolis old regimental belts, now rarely found, are sometimes used from economical motives, but this seems to be a questionable policy as the belt leather is less durable and although it may serve for glazers it is too thin for buff wheels. The *coarse buff*, or *sand buff*, is supplied with Trent sand and oil, the *fine buff*, with rottenstone and oil; these are not used for steel but for softer metal such as brass, Britannia metal, &c., and for horn, tortoiseshell and ivory.

Secondly. Glazers are wheels covered with harder leather upon the face of which emery is attached by glue, they are almost invariably used dry and for steel. The leather used for glazers and polishers in the manufacturing towns of Sheffield and Birmingham is "beast hide," that is, the same leather which when hammered is used for the soles of shoes, the leather is cut into strips and used without having been hammered, the thick and thin parts being selected according to circumstances; glaze wheels require moderately thick leather supplied with emery, and polishers soft thin leather employed with dry crocus.

Thirdly. Polishers are wheels covered with thin soft leather supplied with crocus which is rubbed on dry, without the intervention of glue or oil. In Sheffield one kind of leather is tanned expressly for polishers, it being important that the whole of the grease should be extracted, for if any remain in the leather it will not polish properly. The polishers are used alone for steel, and with very small velocity.

54.—The Smallest Buff Wheels, called bobs, are used in polishing the insides of the bowls of spoons—they are simply discs of leather, nearly an inch thick, known as sea cow or bull neck; they are perforated so as to be mounted on spindles, and are turned of a nearly globular form. *See* Albata.

55.—Buff Wheels and other Leather Wheels, with Wooden Centers differ much in size, those for cutlers usually measure from ¼ to 4 inches wide by 4 to 20 inches diameter, although they are sometimes of twice that diameter; they have wooden centers or discs usually cut out the plankway of the grain and of similar woods to those used for glazers, but they are better when constructed of various pieces in sectors, the best mode being that recommended in article 43, or two layers of sectors each consisting of about sixteen pieces and glued up so as to break joint. The largest of these wheels, say those exceeding two feet diameter, are generally made up of one set of middle sector-like pieces screwed fast between two circular iron plates which are themselves keyed on to the spindle, and then a set of felloes is nailed or screwed around the periphery on either side, making the thickness out to three, four, or even five inches. When the wood centers have been constructed according to some of the above modes, and turned cylindrical or rounded as the case may be, they are turned smooth on the edges and then covered with one thickness of leather.

56.—In Covering the Wheels, the wood and also one side of the leather are plentifully glued, the extremity of the leather is fixed down by two or three nails driven a little way into the wooden disc, the leather is stretched tight and nailed at short intervals, and its other end is also fixed down, and when the entire surface is covered, with one strip if possible, the glue is allowed to dry. It is a matter of great importance that the ends of the leather should be made to butt closely one to the other to make good joints, otherwise the work jumps when a bad joint passes beneath it. The nails are afterwards withdrawn, the leather is turned true and regular with a flat chisel. Sometimes the glazers are required to be very hard, and in this case the leather is soaked in water for a few hours before being glued on the wheel, it is then secured as above whilst in the wet condition, and in drying the leather contracts and becomes considerably harder.

Buff Wheels even of the small diameter of 10 or 12 inches are frequently made three or four inches wide, and covered with soft leather half an inch thick. In such cases the thickness of the wood centers is also very nearly three or four inches, or the width of the leather, which however is allowed very slightly to project, and the sides of the wood are considerably hollowed in the sweep of a circle from the edge to the center to allow the works to be turned round on the edge of the leather in reaching into hollow and rounded angles; as already noticed the buff wheels are used either with Trent sand or rottenstone mixed with oil, and for various materials excepting steel.

Buff Emery Wheels, when the leather with which they are covered has been turned smooth, are brushed over with glue, rolled in a heap of dry emery powder, and afterwards on a smooth board to consolidate the head and make the periphery smooth.

57.—COARSE BUFF EMERY WHEELS are always used dry, and they give off a splendid display of sparks with some of the risk of overheating the work that attends the use of the dry grindstone; the finer buff emery wheels are sometimes used just as explained with the wooden wheels, namely, they are dressed with the emery cake and bouldered down with the flint to bring the head to a smooth and regular condition.

Tool makers use the buffs or glazers immediately after the grindstone, and select the coarse and fine buffs according to the degree of finish required. It may be observed that the dry wheels give the brighter gloss, but do not generally leave the work so smooth as those which are greased.

58.—IN RENEWING THE FACE OF THE BUFF EMERY WHEELS, or in putting on a "new head," the wheel is wetted with a sponge and cold water, and allowed to soak for about an hour, the used emery is then scraped off with an old knife, and the surface of the leather is made somewhat rough; after which it is again glued, and rolled first on the emery and then on a flat board as originally. It is useless to attempt "to put one head upon another," or to apply new emery until that which has been used has been thoroughly scraped off.

59.—THE POLISHERS FOR RAZORS AND FINE CUTLERY are soft leather wheels charged with crocus, which are always used dry. It is necessary that both the polisher and blade should be *hot*, as without a moderate and equal degree of heat, short however of that producing a colour on the steel, the process does not succeed and a good polish is not produced. It is therefore usual with some workmen before commencing work to take a piece of razor steel, which is held against the revolving polisher to prepare it for the work itself, both by raising the temperature of the wheel and crushing and regulating the powder with which it is charged.

60.—ACTION OF THE POLISHER.—Although the polisher is made to revolve much more slowly than the other wheels, the razor is moved to and fro from end to end very quickly and with considerable pressure, to distribute the heat equally; and the blade is not drawn slowly across and off as in lapping, but is moved endlong actively and pulled off quickly. In examining the work, the polished part is occasionally wiped clean with the patch or thick piece of cloth or felt, which serves both to protect the fingers from the heat of the blade and also to supply the polisher with crocus, as the patch is dabbed upon a small quantity of dry crocus close at the workman's hand, and is then rubbed on the polisher to transfer the powder to the wheel.

Occasionally the surface of the polisher becomes very hard from being somewhat scorched by the heat generated in polishing, and its surface is then more or less filled with scratchy lines which disfigure the blade, at such times the wheel is stopped, and the face of the polisher is *roughed up*, or thoroughly scraped with an old razor blade or knife as in erasing writing, in order to remove all the *old head* or polishing stuff, and render the leather a little rough, and quite soft; after which the polisher is recharged by means of the thumb or patch.

61.—THE FLAT SIDES OF WHEELS are not often covered with buff leather except by lapidaries, but in imitation thereof glass and emery paper are frequently

glued on flat chucks of wood and used for finishing the flat surfaces of small works in the metals, woods, ivory, and other substances, the naked wood is sometimes dusted with a covering of pulverized flint, as noticed in the previous article on Flint.

62.—A Flat Polishing Machine actuated by rotary motion has been used for small works, such as brass hinges, parts of locks, etc. The principal part consists of an endless strap of leather, which is put in motion by its encircling a foot wheel as in a lathe, but the strap instead of giving motion to a pulley, passes over and in contact with a narrow flat board, the edges of which are rounded or furnished with small cylindrical rollers to lessen the friction. The strap is charged with emery glued on exactly as in the emery buff wheels. The work when applied on that part of the strap which is flowing over the flat surface of the board is polished with considerable rapidity and a tolerable approach to a plane surface.

In a more usual form, the endless leather or canvas belt charged with glue and grinding emery, runs vertically around a set of six pulleys provided with rims to prevent its displacement. The pulleys of small size are grouped, four as at the corners of a square, with one midway between and above them, this latter having a vertical adjustment to stretch the band; the sixth and driving pulley, of much larger diameter, is placed below the whole and directly under that at the top; the path of the band, therefore, nearly follows the shape of the margins of the envelope of a letter with two of its opposite flaps opened out. Generally there is a second similar grinding strap on another set of guide pulleys on the opposite ends of the spindles, all the pulleys being external to the frame of the machine. The yielding straps of these machines are employed for cleaning and finishing taps, gas-fittings and other small brass castings which only require a surface smoothness, and the work is held and twisted about upon the straps in the hands. Some further varieties of these endless strap grinders are mentioned in Chapter IV.

Section F.—Wheels of Cloth, or Cloth and List Wheels.

63.—The Cloth used for Wheels is usually thick woollen cloth such as that for white great coats, and the blankets of printing machines, felted cloths are likewise used. Sometimes the cloth or felt is simply glued around the edge or upon the face of the wooden wheels precisely the same as in buff wheels, and is employed for similar purposes.

64.—Opticians' Cloth Tools, consist of a circular piece of cloth cemented by means of pitch upon the surface of one of their brass concave or convex tools of the required curvature, the cloth if new is seared with a hot iron to remove the nap before it is cemented down. Sometimes the opticians' metal tools are covered with a broad strip of thick silk or lute string, which is folded around the edges and cemented at the back of the tool. The cloth and silk tools are always used with putty powder. *See* the articles Lenses Chap. VIII.

65.—The Lapidaries Cloth Mill is a face wheel having an annular surface about two inches wide, there is first a center of wood of about 6 inches diameter,

then a spiral coil of wide list or cloth which is wound up closely until the diameter of the cloth becomes about 10 inches. The cloth is secured partly by tacks driven first into the wood centers, and then by small nails driven into the plate of wood that forms the back, and the outer coil is nailed around the edge of the principal disc, so that the whole forms an annular face with a loose pliant surface, the top of which is dressed level with an iron heated to a dull red. *The list or selvedge* of woollen cloth is commonly used, and as this is thicker on one edge than the other, it is the practice of many lapidaries to roll on two coils at once by aid of two individuals, the thick edge of the one coil being downward and of the other upwards; this mode equalizes the tension and prevents the list gathering up as a cone—and in this case it is only usual to nail the list at the beginning and ending of the coil.

The list wheel is generally employed with pumice-stone and water, and from its elasticity it yields admirably to the curved surfaces of shells and stones; it is also employed for plane surfaces on many soft substances, as explained under the article ALABASTER in this Catalogue.

66.—IVORY WORKERS' LIST WHEELS consist of 10 to 20 circular pieces of cloth screwed fast between two discs of wood about 2 or 3 inches smaller than the cloth, which therefore forms a pliant edge projecting an inch or upwards beyond the wood, which is well adapted to the curvilinear surfaces of umbrella or parasol handles, and many such works—the wheel is fed with Trent sand, loam or chalk, it is better to have one wheel for each of these substances. *See* IVORY.

67.—MOPS OR DOLLIES, a variety of cloth polishing wheels, so called in Sheffield and Birmingham respectively, are employed in the final polishing of nickel and electroplate, brass, copper, etc. They are made of a large number of circular pieces of calico, or of swansdown, a similar material with a soft nap on the one side. The collected sheets are placed together with the warp of every three or four at a different angle to that of the same number of their neighbours; and the whole are held together by central pieces of thick wood, about one-quarter the diameter of the mop, fixed on either side by strong wire nails passing completely through and clenched or rivetted. The wood nave has a plain central hole by which the mop is screwed on the worm of the polishing spindle, precisely like the screw worm chuck of the soft wood turner; in revolution the loose flaccid sheets stand out by centrifugal force and spread but little in width of edge; the work is applied to their frayed edges with any of the finer polishing powders. Calico mops and dollies range from 5 to 15 inches diameter, and from half an inch wide with 30 laps or sheets, to 3 inches with 150 to 180 laps. In the swansdown mops the thicker material allows only about one-third the number of laps; the latter are sometimes held together by a single spiral line of stitches passing through them from side to side from the nave to the circumference.

SECTION G.—WHEELS OF BRISTLES, OR WIRE, OR BRUSH WHEELS.

68.—WHEEL BRUSHES OR BRUSH WHEELS are very largely employed in the arts;

they are made both hard and soft in bristles and cow-hair, and of all diameters from about 2 to 8 inches, with the hairs placed radially so that the outer rows lean a little towards the center to give them more stability.

Wheel brushes are used with emery, crocus, rottenstone, putty powder, whiting, and all the polishing powders both with oil and dry, and are employed for curved, indented, chased, open and pierced works, but it is to be remembered the brush rapidly obliterates keen angles, the preservation of which requires particular care and patience and the employment of hard buffs or the wood and metal polishers already described—as the greater the degree of exactness that is required in the angles and edges of polished works, the greater should be also the degree of hardness in the face of the grinders and polishers employed.

69.—Wheel Brushes made of Steel, Iron and Brass Wire, some with edges shaped like those mentioned in the last article, and others with the tufts of wire at right angles to the axis to give a wider and looser cylindrical edge, are made of about the same sizes as those of bristles. Those having stiffer wires are used after the manner of scratch brushes, made of similar wire and for the same purposes—for cleaning and scratching the metals preparatory to gilding and silvering, &c. The softer kinds made of medium and fine brass and German silver wires, are employed for polishing or giving a semi-polish to those works which as a whole or in parts cannot be conveniently applied to the more accurate and preferable buffs and wood polishers. The ends of the wires are frequently bent or "crimped," to reduce the abruptness with which they would otherwise encounter the work.

70.—Bristle and Wire Cup Wheel Brushes.—In these the wires, held together and soldered in a metal socket to screw on the polishing spindle, spread out in diameter and are cut as to their ends into a conical spherical curve, to the same shape as that of an ordinary shaving brush; in others of this kind the ends of the group of wires or bristles are cut to a flatter or mushroom curve. The cup brushes do not usually exceed 3 or 4 inches in diameter, and are used within spherical and other cavities which cannot be reached by the wheel brushes.

71.—Swing Wire Wheel Brushes are a kindred variety, used within cups, sugar basins and other vessels of which the mouths are smaller than their bulging sides. A metal socket, 4 to 6 inches long, to screw on the polishing spindle, carries four thick rings of round section attached in the solid, radially and equidistantly around its opposite extremity; and on these by means of similar round rings, depend brass, German silver, or fine steel wire tassels. The group of tassels held together by the hand, is introduced within the vessel and the soft brushes spread out in one plane on revolution and, confined by the diameter of the work, reach those parts within it which cannot be touched by the cup brushes. The long tassels are forced to take a curved form in respect to their length and cannot stand out radially as they sweep round within the work, hence their action is smoother and more favourable to polishing than that of other wire brush wheels.

WHITING is common chalk, ground, washed for the separation of sand and other impurities, and dried in lumps. *See* Chalk.

WOODS.—Many variations will be met with in the modes by which the woods are polished, which depend greatly on the qualities of the woods themselves as to hardness, fibre and colour; consequently under this head it is preferred to follow generally the arrangement of the turnery and other woods, enumerated in the tabular view on page 70 of the first Volume.

Turned Works.

1.—Woods of Soft Grain and Light Colours, such as alder, ash, small beech and birch wood, sallow, willow, and also holly, horse chesnut, sycamore and some others, which woods are used respectively for common toys and the best Tunbridge wares, are in many cases so smoothly turned as not to require any polishing whatever, or at most, only the friction of a few of their own shavings.

The less-experienced may find it necessary previously to employ glass paper it is then desirable to polish the work first whilst it revolves in the one direction, which lays down flat such of the loose filaments as are not polished off, and then by reversing the motion of the lathe, these parts are as it were brushed up and generally removed. The alternating motion of the pole or spring lathe, fig. 20, Vol. IV., was therefore desirable in polishing such woods. A few shavings are mostly used to rub the revolving work after the glass paper to remove the loose dust and brighten the surface. Many of the toys and works here referred to are coated with the white sandarac varnish, and some few are subsequently polished.

2.—Woods of Medium Hardness and Colour, namely, apple tree, plum tree, and old beech wood, box, elm, oak, walnut, and also mahogany and some others, although in general turned with the tools for soft woods and in the same manner as the first group, are prepared for polishing in almost every case with glass paper. They are then generally coated either with boiled linseed oil, which is applied with a brush or rag, allowed to soak in for a short time, and is afterwards rubbed off with shavings; or else they are covered thinly with bees-wax dissolved in turpentine, applied on a flannel. As much as possible of the beeswax is afterwards rubbed off with a clean flannel, to prevent the stickiness that occurs from an undue quantity of the dissolved bees-wax, which never thoroughly hardens. Some workmen judiciously add a small quantity of powdered resin to the bees-wax and turpentine, this gives a little more consistency to the wax and lessens its stickiness, but the quantity should be moderate.

Some workmen use the wax in its natural state, and rub it in by softening it with the friction caused by a stick of deal wood, applied successively over the surface of the work, and afterwards remove as much as possible of the wax with a flannel. For woods that have been stained black, the black wax or composition prepared for the shoemakers, (and called *heel-ball*,) is almost

always thus applied, unless indeed the works are lackered after the manner of French polishing.

3.—Woods of the Hardest Grain and Darkest Colours, and some others such as the foreign hard woods for turnery enumerated in the tabular view on page 70, Vol. I., are sometimes polished precisely after one of the modes already described, in other cases they are lackered, the mode of fulfilling which will be afterwards described, but when the lacker is used it should be applied directly after the glass paper, and without either oil or bees-wax having been used previously.

It should however be observed that careful workmen place but little reliance on the advantage to be derived from polishing, as in truth the work should be left so smooth and exact from the turning tool as to require little or nothing to be afterwards done to it. The practice employed by the mechanist of rubbing the emery or glass paper face to face to abrade any coarser particles is here likewise desirable, as also that of wrapping the papers around a parallel slip of wood in polishing flat surfaces and some others, as this tends to preserve the keenness of the angles and fillets of works turned in the woods. In polishing within the bottom or lid of a box, it will be found advantageous to wrap the fine polishing paper around a small cubical block of wood, one or two of the faces of which are rounded or made cylindrical; this will tend to lay an even flat grain over the work.

The superficies are nevertheless liable to be left marked or scratched with rings from the action of the glass paper on the revolving work, which lines visible on cylinders are still more pronounced on surfaces; and this evil is only partially avoided by keeping the glass paper in constant motion by travelling along cylinders and to and from the center on surfaces. Hence it is good practice, especially with the coarser glass papers, to stop the revolution of the lathe from time to time and to arrest and turn the work round from place to place by the hand laid on the mandrel pulley, whilst the glass paper is rubbed lengthwise along cylinders and diametrically across surfaces, that the one set of lines or scratches may cross and obliterate the other; a rather frequent alternation in this manner, made also with gradually finer to worn out glass paper, leaves the work in better condition for subsequent polishing.

4.—Hardwoods Polished with Tripoli.—A lustre that may be termed a natural polish is given to some of the hardwoods of close grain, as in the best musical instruments made of cocoa wood and ebony, and some other works; that is to say the surface of the wood is polished entirely by abrasion, the same as the metals, marble, and many other materials. The process is sometimes conducted with tripoli powder, at other times with Dutch rush: and it is needful in either case that the work should have been smoothly turned, and then rubbed with fine glass or emery paper, which latter is frequently preferred.

A moderate quantity of yellow tripoli is placed on flannel slightly moistened with oil, and applied just like glass paper, the motion of the lathe being occasionally changed in direction, and sometimes stopped, whilst the flannel is rubbed lengthways, to diversify the direction of the friction thus applied. It is desirable not to use a second supply of tripoli, unless at an early stage,

but to allow the powder to become embedded in the flannel and worn down to a smooth face, on which account but little oil should be used. The tripoli then becomes gradually finer and drier, and with careful management will produce a surface entirely free from scratches and highly polished, without the adventitious aid of lacker; this mode produces a far more durable surface wood being a much harder substance than the shell lac, the basis of the varnish for hardwood.

5.—HARDWOODS POLISHED WITH DUTCH RUSH.—A dozen or more short pieces or joints of the rush just divested of the knots and tied up at the ends as a faggot are used with water, applying all sides of the rush to wear it down smooth alike; and in this case, as in the last, the same polisher is continually used throughout the process in order that it may become finer with the progress of the polishing. After a sufficient period and when the rush feels inactive, it is laid by and allowed to dry, when it is again used in the dry state, and serves to bring up a polish nearly or quite equal to that produced by the tripoli. Some artizans employ subsequently to the rush, putty-powder or rottenstone, but this is only admissible when the surface of the wood is so smooth and dark as to be incapable of retaining the powders in its pores, or of becoming stained by them.

6.—TURNED WORKS CARVED AND THOSE ORNAMENTED with the eccentric chuck, or revolving cutters, &c., should not require and do not admit of any polishing beyond the use of a clean brush dry or as follows; sometimes a drop of oil is placed on the brush, but the oil although it may leave a temporary gloss, is eventually absorbed in the wood, and renders the surface more dull than before; a minute quantity of the wax polish mentioned in article 2, may be spread on the brush, the work not oiled, and the wax if not in excess gives a brilliancy which may be always renewed upon work that has become dusty by subsequent dry brushing.

Occasionally the ornamented works are coated slightly with thin varnish laid on with a brush, this is not to be recommended, and unless the patterns are very bold, and the varnish is dexterously applied, it is almost certain to fill in the hollows to a degree that is highly prejudicial to the appearance of the work.

Sharp tools and correct treatment completely obviate the necessity of any polish on engine turned works in hard wood, beyond that of a dry brush, when the proper course is pursued in their production, namely, *that of polishing very highly the facets forming the cutting edges of the tools*, in the manner that is elsewhere explained, and allowing the tool to cut gradually, or without plunging it too rapidly or too rankly into the work.

FLAT WORKS.

7.—FLAT WORKS IN WOOD.—The majority of the joiners' works wrought with the plane, and others executed with the file, come under this denomination. Their flat surfaces are in general scraped with the ordinary joiner's scraper, a thin plate of sheet steel, the edge of which is sharpened on the oil-stone

and burred up with the burnisher. (*See* page 484, Vol. II., fig. 331.) Afterwards the wood is cleaned with glass paper, of two or more sizes, wrapped around a flat piece of cork glued on a block of wood about 3 × 4 inches square, or on a piece of wood on the flat surface of which one thickness of woollen cloth is stretched and nailed around the edges which acts with greater accuracy than the elastic cork, and keeps the work flatter.

8.—Small Flat Works in Wood are often rubbed *upon* the sheet of glass paper, which is then laid on the flat bench or other board—a practice analogous to that pursued by watchmakers and others. In some cases also small flat surfaces in wood are finished on face wheels, plane discs of wood on which glass paper is glued, which practice is somewhat common for the mechanism of piano-fortes.

9.—Polished Flat Works.—It may be generally said that the several modes of polishing already described in reference to turned works of wood, are all more or less practised also in flat works; but the so-called French polish, to be hereafter spoken of, has obtained nearly a monopoly in the embellishment of furniture and other works; the carved surfaces of which are still, however, mostly varnished with a brush as in painting, and not by attrition. But the old fashioned polish due to linseed oil, constantly applied for a year or two, although tedious, produces an equally beautiful and far more lasting polish, although it must be admitted the oil has the effect of rendering the woods somewhat darker. In conclusion of these remarks the reader is referred to the article Marquetry in this Catalogue.

WROUGHT IRON.—The parts of machinery made of wrought iron are polished as described in the general article Machinery in this Catalogue: two other examples are alone here given.

The parts of stoves and similar works in wrought iron, are sometimes ground, but in general they are filed, draw-filed, rubbed with an emery rubber, and burnished with the two handed burnisher having a stirrup for the foot; as in such works the glittering polish on a comparatively scratchy surface, is considered to be good enough for the purpose.

Round knobs, crooked arms, bows of keys, stirrups, bridle bits, and pieces free from sharp angles, are often polished by wrapping once or twice around them, a piece of soft rope or string smeared with the polishing stuff; and by using a sawing motion with the two hands, a considerable friction is applied all around the objects. The screws of corkscrews are mostly thus dressed. Objects thus polished may be subsequently kept in condition by the *chain burnisher*, for which convenient appliance *see* Burnisher, article 4.

XYLONITE, also known as celluloid; an artificial homogeneous substance of exceptionally fine grain, used as a substitute for ivory, horn, tortoiseshell, &c. Made of paper, cotton, and other fibrous matter treated with nitric and sulphuric acids; the result dissolved in spirits of wine, camphor and colouring pigments being then added; moulded under hydraulic pressure into rods, tubes, &c., and rolled into sheets from $\frac{7}{1000}$ of an inch to about two inches in

thickness; all pieces adhere with solid imperceptible joints when pressed into contact after coating with camphorated spirit as a surface solvent. The process of production carried out by the British Xylonite Co., London, was discovered and patented by Mr. Alex. Parkes, 1856. Employed for an endless variety of purposes, including knife and umbrella handles, pianoforte keys, combs and brushes, surgical and electrical appliances, buttons, toys, &c.

Thin sheets of the base or natural colour, a light tawny straw, are transparent as glass, and receive fine graduations for protractors and other mathematical instruments. Colours of uniform tone throughout the material given by pigments, metallic oxides and aniline dyes;—amber, dead, cream and blue whites, flesh colour, pink, coral, ruby, chocolate, brown, slate and black. Variegated colours given by manipulation in the addition of the pigments;—close imitations of agates, clouded amber, carnelian, ivory, malachite and all varieties of horn, marble and tortoiseshell, in which second group all the veins and mottled blotches of colour run completely through the substance.

The life or grain in natural ivory is so well simulated that, in many cases, it is difficult to detect the material as factitious; beyond this, xylonite is more elastic and less brittle, does not absorb grease, and does not deteriorate with age like ivory, and, in view of the growing scarcity of the latter, it is to be hoped that xylonite may entirely replace it for table knife handles, carriage fittings, and similar purposes upon which ivory is now practically wasted.

2.—Working.—Turns with facility, without the smallest tendency to crack or chip, with any of the tools used for hard or soft wood, employed just as on those materials, but more generally as scraping tools. Files, planes, saws and scrapes with ease; most surfaces are produced by keen edged scrapers, old razor blades, chisels sharpened on their ends and sides, and the carpenter's two-handled drawing knife, all ground and sharpened to the angle of 20°, the edge held nearly at right angles to the work. The blanks for combs previously immersed in cold water have their sides tapered from the back to the front edges by a few strokes given with the last named tool. The carpenter's scraper, its edge burnished over as described p. 484, Vol. II., and small pieces of similar steel plate inserted about one quarter of an inch apart square across a wood stock, precisely like the French stonemason's *chemin de fer*, fig. 136, serve for correctional purposes, and are used with the work dry. Floats, or coarse single cut files of flat, half round and triangular sections of all widths and dimensions, are used for curved and many flat surfaces. An excellent material, in every way suited to ornamental turning.

3.—Polishing.—Turned and straight works, generally as left from the tool but sometimes smoothed with glass paper, are polished, first, with sifted powdered pumice stone and water and, secondly, with natural silica, the latter prepared, ground and washed to a uniform white powder as fine as flour emery, or with rottenstone, as the work may be of light or dark colour, all applied on buff leather rubbers with oil. A still more lustrous polish, if required, may then be obtained by putty powder moistened with methylated spirit, and used on the buff until dry. In wholesale production the works are polished on cloth

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and calico mops or dollies, *see* WHEELS, article 66, fed with the silica or rottenstone powders and oil.

Carved works and those executed in ornamental turning may be polished with these powders or with whiting and oil applied in the ordinary manner for polishing ivory, which see; as an alternative, a brilliant polish is obtained by moderately warming the work in an oven, then plunging it for a moment in *Acetone*, a volatile spirit obtained by the distillation of the acetates of the alkaline earths, and immediately returning it to the oven until dry; taking care not to touch the work with the fingers whilst it is still wet with the liquid.

4.—Striking, pieces of sheet previously warmed on steam plates are punched out to shape and dished into trays for chemical use, boxes, hemispheres, &c. in fly presses, the dies heated by steam jets; for moulding more solid works the material, first boiled in water, is placed between dies and subjected to hydraulic pressure.

Chemically a di-nitrous cellulose, xylonite has been erroneously said to belong to the class of explosive nitro-cotton compounds. Col. Majendie, C.B., H.M. Chief Inspector of Explosives, experimented in the matter in 1882, and again, in a paper read at the London Institution, 1891, he said, "It is only due to the manufacturers (who I regret to say have experienced some difficulties from misapprehension on this point) that I should state, as emphatically as I can, that Xylonite is not explosive, though of course highly inflammable." —Many thousand tons have been produced during the past fifteen years by the British Xylonite Co. without one single instance of spontaneous combustion.

ZINC.—Door plates made of rolled zinc are cut out, scraped to a clean surface, hammered flat and then planished, after which they are by some workmen smoothed, 1st, with a stick of blue stone and water; 2ndly, with emery paper wrapped on a piece of wood or cork, and moistened with oil; 3rdly, with rottenstone and oil on a coil of list.

Other workmen employ immediately after the scraper, 1st, pumice-stone either in the lump or powder; 2ndly, flour emery and oil on a flat woollen rubber; and 3rdly, rottenstone in the same manner.

ZINCOGRAPHIC PLATES FOR PRINTING.—In order to give these the fine grained surface required in this branch of the graphic art, they are, 1st, rubbed with ordinary sand, and 2ndly, with fine sifted sand, the rubber of list rolled up tight and used with water; the zinc plate is then ready to receive the drawing which is made with the ordinary lithographic chalk upon the plate, or is transferred from the transfer paper and fixed by an acid preparation.

ZIRCON is the generic name of three varieties of gems known as the Hyacinth, the Jargoon, and the Zirconite, they are sometimes so hard as to require to be cut into facets with diamond powder the same as Sapphires. "The exposure of some varieties to heat, deprives them of their colour, and they are said to have been sold in that state in place of the diamond."

CHAPTER II.

GRINDING AND SHARPENING CUTTING TOOLS.

SECT. I.—GRINDING CUTTING TOOLS ON THE ORDINARY GRINDSTONE.

The various apparatus, materials and processes employed in grinding and polishing having been generally described in the foregoing Catalogue, the present chapter will be devoted to the more detailed illustration of the methods of restoring the edges of the most usual cutting tools; and, as the edges of all such tools are rectilinear or circular, or combinations of the two forms, the descriptions given will serve to convey a sufficiently precise idea of the methods followed with any tool not particularly named.

For convenient reference the chapter will contain one section on the grinding of cutting tools on the ordinary grindstone, with some collateral matter, one section on grinding tools and drills on emery wheels or factitious grindstones, a third on the sharpening of cutting tools on the oilstone, followed by one on setting razors; and in all the foregoing it will be observed that the tool is generally applied with the unassisted fingers, the use of any kind of guide being rare, except in the case of drills. The succeeding chapter will describe various modes of grinding and sharpening cutting tools and saws on artificial grinders, in which the guide principle is nearly always essential.

Of all the tools in the workshop the absence of the grindstone would be the most severely felt, for without it the restoration of the edges of the tools would be scarcely possible, and upon their perfection much of the practical success of cutting processes depends.

Sharp tools, produce with the least expenditure of time, surfaces so nearly finished as to require but very little polishing, whereas blunt tools leave the lines and mouldings less accurately defined, and the additional friction or polishing

employed to gloss over the defects makes a bad case worse and obliterates all those keen edges which impart to the work a defined and exact character.

The ordinary mischief in polishing is excess, and the operator is most strenuously counselled to *polish the tool* upon the oilstone, or other fine abrasive employed for setting the edge, and he may be assured that it will then not only cut in a much more agreeable manner, but also that it will impart its relative degree of perfection to the work, in like manner that the coin or medal is polished by the bright and accurate surface of the die, and not by any subsequent process.

The primitive tools whether of stone, wood, bone, or metal, were probably sharpened by rubbing them on flat gritty stones, a method still resorted to in the absence of other

Fig. 1.

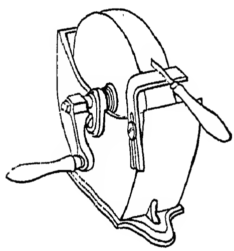
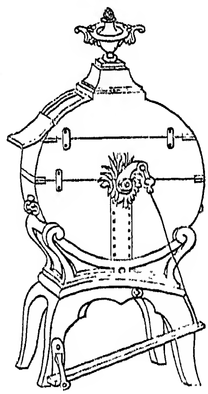


Fig. 2.



means, although when the substances are hard and much is required to be ground away it is exceedingly tedious; and perhaps one of the earliest efforts at mechanical contrivance, coeval with the introduction of the draw well and the potter's wheel, the latter also a revolving flat stone, was the rotation of the grindstone upon an axis fixed within a central aperture cut within the same, and now called the eye. The spindle was doubtless supported in a horizontal direction in notches made in the top of two stakes fixed in the ground, or in some simple frame, and a transverse handle was fixed to the axis to enable one man to turn round the stone, whilst another applied the tool to be ground to its surface.

This supposed earliest apparatus, somewhat improved in its mechanical details, is still met with in almost every village and even yet serves in many workshops, although side by side, it may be said, with far more economical methods that have been in use for at least three centuries. Small grindstones not exceeding a few inches diameter are commonly mounted in a similar manner in troughs or boxes of wood or iron; one of the best forms, fig. 1, carries stones ranging from twelve to about fifteen inches in diameter, and the bearings for the spindle are fixed to the cast-iron trough, as also a movable rest for the tool; stones of these dimensions may be easily turned by the left hand, whilst the tool supported on the iron rest is held in the other. Similar but much smaller stones usually in wooden troughs are generally employed for the small tools used by watchmakers, engravers, jewellers and others, for which the quantity of material to be ground away is inconsiderable.

The figure on the next page is copied from an engraving in a work by Hartman Schopper, printed at Frankfort on the Maine in 1568. In this case the stone is moved by a treadle, which is an admirable plan for grindstones from about twenty to forty inches diameter, used for sharpening tools, as the weight of the stone serves as the fly wheel, and the whole process may be carried on by one individual. This mode is less common than it deserves to be, the treadle should however be extended beyond the crank rod, and the foot should be applied at the opposite end, the same as in the ordinary turning lathe.

A far later example, fig. 2, is reproduced from one of numerous engravings of grindstones and of the details of their frames and mountings given by Hulot, 1775, a professional turner, whose excellent treatise commenced upon the most comprehensive scale appears, unfortunately, to have been completed only so far as the first volume.* This grindstone, about 24 inches diameter, is interesting, inasmuch as its spindle runs in bearings fixed to the upper ends of vertical racks that work in slides mounted on either side within its external casing and are raised, to lift the stone out of the water, by equal pinions on a second spindle below, the end of the latter, squared for its

* L'Art du Tourneur Mécanicien. Par M. Hulot père, Maître Tourneur et Mécanicien brévetè du Roi. Paris. 1775. Folio.

key, being alone visible in the engraving projecting through the side of the stand. These racks were employed also with the smaller grindstones turned by hand; and the author mentions that he had constructed this sumptuously-mounted grindstone for more than one Royal Personage, amateur turners, whom he numbered among his patrons.

An oval tub made of staves like a barrel to serve as the

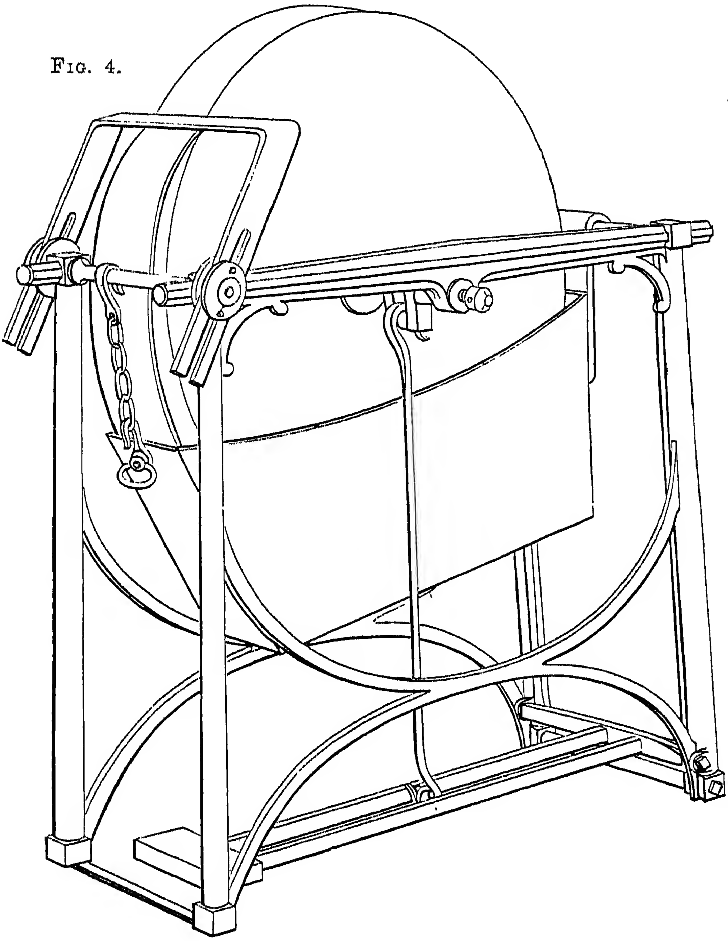
FIG. 3.

trough is occasionally met with, its diameters about as two to one, with the axis of the stone placed across the shorter, the necks of the spindle running in collars of hard wood or metal fixed to the sides of the tub; the latter is supported on four legs at a convenient height and the treadle is joined to the back legs, with a rod to the crank, which is external to the bearings as in former figures. The trough, however, is usually an oblong wooden box similarly mounted on legs with a treadle, and should have a tap, or spigot, to run the water off when the stone is not in use.

Grindstones are also fitted up in a variety of other frames

either of wood or metal. The ends or pivots of the spindles are either cylindrical, conical, or turn between conical center points. The water-trough is stationary in some cases, in others it is joined to the frame by a joint or hinge at the one

Fig. 4.



extremity and supported by a chain at the other, in order that it may from time to time be lifted up to moisten the edge of the stone, which, as previously explained, should never be allowed to rest in the water, as that part would be softened and would therefore wear away more rapidly than the remainder and hasten the departure from circularity. The frame is

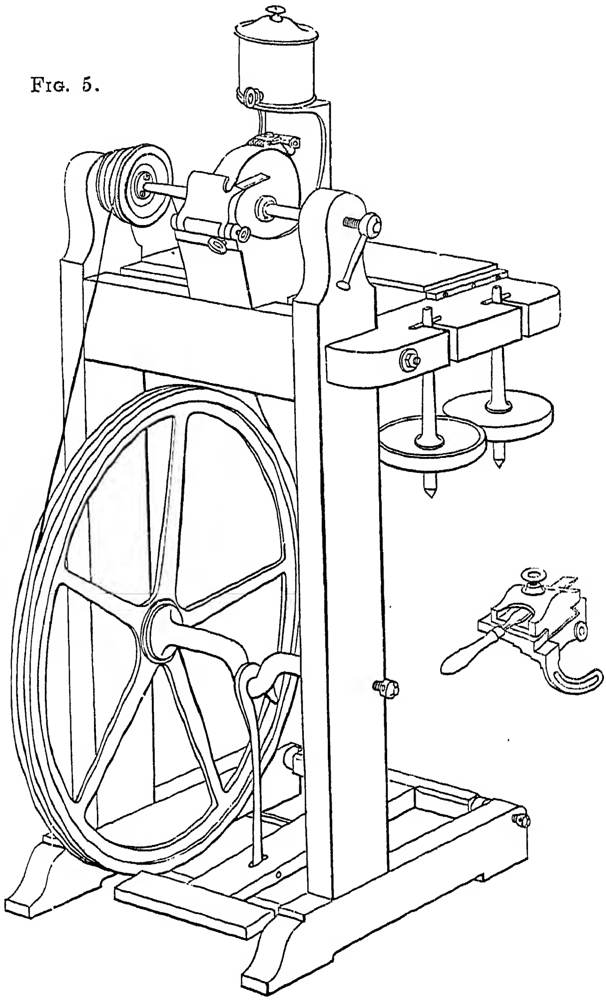
generally provided with a support on which the tool or the hand is rested, and also with a splash-board to catch the wet thrown off by the centrifugal force and conduct it back into the trough.

Fig. 4 represents an arrangement suitable for grindstones of from two to three feet diameter. In this case the frame is entirely of iron; the stone is worked by a treadle leading to the cranked spindle, mounted between centers; and instead of the stone being fixed to the spindle by wooden wedges, which are liable to be disturbed from their original setting by extreme change from wet to dry, they are secured by the improved plan, introduced by Holtzapffel & Co. A lead center is cast in the eye of the stone, by means of a proper mould, so as to leave a central and cylindrical aperture, and the spindle is turned to the corresponding diameter and provided with a screw and nut, which press the stone against a flange on the spindle, which has a pin to ensure the rotation of the stone. In this manner the stone is fixed with great solidity, and with the power of removal from one spindle to another when the reduction of the diameter of the stone calls for the change. Fig. 1 is also mounted upon its spindle in a similar manner. The rest for the tools in fig. 4 admits of being placed at any height or distance from the stone that may be required, and a leather flap suspended from it serves the purpose of the splash-board, mentioned in the last paragraph.

The grindstones used in engineering workshops are usually driven by power, and are sometimes mounted in wood frames but more generally in those of metal. The latter in cast-iron take the form of one-half of a flat drum with a spreading foot or pedestal in the same casting; plummer blocks on the top edges receive the spindle, one end of which is extended and carries a strap pulley beyond the frame, driven from a corresponding pulley from the shaft above. Countershafts with fast and loose pulleys are seldom used, for the stone being in frequent requisition is usually kept constantly running. A tool rest is fixed at each end of the frame for the convenience of using both sides of the stone at one time; that revolving towards the tool drives back, or rather, does not produce a wire edge, and is employed for turning and planing tools for iron which are used direct from the grindstone, but tools for

brass and other materials which require subsequent sharpening on the oilstone may be ground on either side. A small stream of water, controlled by a tap, just sufficient to moisten it, is

FIG. 5.



allowed to fall on the revolving stone during the grinding; and the upper part of the grindstone is sometimes protected by a cast-iron cover attached to the stand, which also serves to carry the reservoir for the water.

A small grinding and polishing machine adapted for the use

of the amateur is represented in fig. 5. This machine is fitted with five spindles, two of them have grindstones, the one for rough usage, the other to be reserved for the more particular tools, the three other spindles are fitted with a metallic lap of lead hardened with a little antimony, a buff wheel with emery, and a circular brush. The spindles are driven by an iron foot wheel and treadle, somewhat after the manner of a lathe, as explained in the Catalogue under the head WHEELS, article 7. The stones of about 7 inches diameter are fixed upon roughened iron spindles by means of melted lead poured in between the two; by this plan such small stones are not liable to be split, which frequently occurs with wooden wedges, either from their being over driven in the first instance or from their subsequent expansion by wet.

The spindles are sometimes made with centers at each end, with a pulley on each, but they are now far better as made with a center point at the one extremity, and a truncated cone with a driving pin at the other, which work respectively between a center screw and a hollow notched cone fixed in front of the pulley, which latter is free to revolve upon its own bearing, when connected by the band with the foot wheel and treadle beneath. By this arrangement which is somewhat similar to the center chuck and driver of the common turning lathe, the spindles can be readily exchanged by unwinding the center screw and without the displacement of the band. The machine is provided with two iron rests for the tools, that are each applicable to the edges of the grindstones and the face of the lap, they are of different bevils and susceptible of adjustment for height by a screw. A water cistern with a drip valve is mounted above the back of the cast-iron trough, the water from which falls upon the stone slightly in advance of a piece of tow, held in contact with the stone by a clamp, this effectually prevents the water from being thrown off by the centrifugal action and keeps the stone uniformly moist. A box at the back of the frame serves to contain the polishing powders, brushes and scraper. The machine is sometimes provided with an additional tool rest to assist in grinding chisels, flat and other tools to uniform cutting bevils throughout the widths of their rectilinear edges. This, shown separately, is held as a hinge, in the same manner as the

plain rests, by means of a long pin which passes through it and two ears on the front horizontal edge of the water trough, and, in addition, by a quadrant and thumb screw at the side, so that its flat top may be fixed sloping downwards at all angles required to give the cutting bevils. The tool holder travels freely as a transverse slide upon this table parallel with the axis of the grindstone, and is moved to and fro across the edge of the stone whilst grinding; the shaft of the tool is held by a screw and clamping piece from above, gravers, the bevils upon which stand diagonally from corner to corner of their square stems, in a corresponding V groove made across the otherwise flat lower face of the tool holder.

The ordinary cutlers' wheel and the large grindstones for the manufacture of tools from their forgings have been already described in the catalogue, pages 124 to 128, and their arrangement will be sufficiently obvious without the aid of diagrams. Large stones are however sometimes furnished with a contrivance called a *dolly bar*, for adjusting the height of the water in the trough without the continual necessity for adding small quantities to maintain it at the most suitable level; the dolly is a large wooden bar suspended from a pulley attached to the splash board and partially immersed in the water, when the dolly is lowered it causes a corresponding elevation of the water so as just to reach the grindstone. This contrivance in common with all those of the grinder is exceedingly simple, and although dirty the grindery is often very picturesque.

The restoration of the edges of most cutting tools for wood and soft substances is effected by the successive action of the grindstone and oilstone, the former being employed to remove the principal bulk of the material, so as to prepare the tool for the action of the slower but more delicate oilstone, which produces a much keener and more accurate edge than can be obtained with the grindstone. Tools for cutting the metals and hard materials are frequently left from the grindstone without the application of the oilstone, which is chiefly resorted to for setting a smooth edge upon the finishing tools.

Tools that are required to possess a delicate edge of a defi-

nite form, should in all practicable cases be ground upon the one bevil only, the second face then admits of being carefully formed in its manufacture, and the accuracy thus given should be scrupulously maintained, as it is clearly much easier to produce the required form by the abrasion of the less important face, than when both angles of the edge have to be renewed every time the tool is sharpened. For example, the axe and chipping chisel which require considerable strength, and but a moderate amount of accuracy, are commonly ground with two bevils, while the plane iron and paring chisel, which require accurate edges and greater delicacy, have the one face made quite level in the first instance, and in the process of sharpening the second face of the angle is alone operated upon; in screw tools, and moulding tools for turning, this is still more imperative. The razor, which requires delicacy of edge rather than accuracy, is sharpened on both faces, but in this case as will be shown hereafter the back of the instrument serves as a guide for the formation of the edge.

The grindstone should be kept in order so far as possible by the equal distribution of the wear; narrow tools especially should be constantly traversed across the face of the stone to avoid wearing the latter into ridges, and the extreme edges of the stone should be exposed to their fair amount of work, or otherwise the stone will become hollow and unfitted for grinding broad flat tools. By the equal application of the tools, the face of the stone may be kept tolerably flat with but little recourse to turning or hacking, which processes have been explained in the preceding catalogue under the head Wheels, articles 14 to 17. When however the stone loses its circularity, or becomes eccentric from being worn irregularly, it is better at once to resort to one of the means of correction, otherwise the stone becomes rapidly worse, and the difficulty of holding the tools steady is considerably increased.

As a more exact method of keeping grindstones in order, two grindstones are sometimes mounted with their axes parallel and adjustable by screws to keep their surfaces always in contact, and by giving them different surface velocities they respectively abrade and correct each other; this contrivance has been more fully described in the Catalogue under the head of Wheels, article 13.

The processes of hacking and of turning with the point of a steel or iron bar, described in the Catalogue under the head of WHEELS, articles 14 and 15, are generally followed for the restoration of the worn edge or "face" of the grindstone, but other methods are more or less employed. The carbonate diamond tool, already described, has been employed, but, except for emery wheels, it is practically superseded by Mr. Brunton's ingenious disc tools. This tool, fig. 7, consists of a small steel disc, bevilled from one or both faces to give it a quasi-sharp periphery, or else of a thin sheet steel disc cupped or dished up to the form of a truncated, short hollow cone, and turned true upon its thin edge; these tools are mounted to revolve freely upon the end of a stem, which is grasped in a species of sliderest by which they are traversed across the edge of the revolving stone, against which latter they themselves revolve by simple surface or rolling contact. The action of the disc tool is very interesting; in turning a grindstone with the point of an iron or steel bar both suffer attrition, for the groove made in the stone by the bar at the same time grinds the point of that away and, as already stated, it is continually necessary to turn the bar partially round in the hands to present a fresh angle to the work. The disc tool as it travels across the edge is also held in forcible contact with the revolving stone, and if it were quiescent its delicate edge would be rapidly, indeed instantly, destroyed, but, owing to the constant rolling motion given to the disc by its contact with the revolving stone no part of its edge can stay long enough to suffer, and it may be said that each minute point around the edge of the disc as it attacks and does its work upon the stone, at the same moment slips away from danger. The stone is turned true by a few traverses of the disc, and the perfection of the escape of the tool is shown by the comparatively slight wear it suffers in the process; the wear indeed bears no comparison with the work effected now under consideration, nor yet when the tool is used upon granite and other hard materials, as mentioned in a later chapter. The wear moreover is in one respect beneficial, inasmuch as the abrasion maintains the necessary true circularity of the edge of the cup, as that is slowly worn away in use, on the other hand the wear thickens the angular edge of the solid discs

and their bevils have to be reground; the cup or hollow cone disc tool is of the same thickness throughout its substance and, therefore, does not suffer in this respect, but only from reduction of its size, which is of little importance.

The illustration fig. 6 indicates the general form of the apparatus; the base plate pierced with slots, by which it is

Fig. 6.

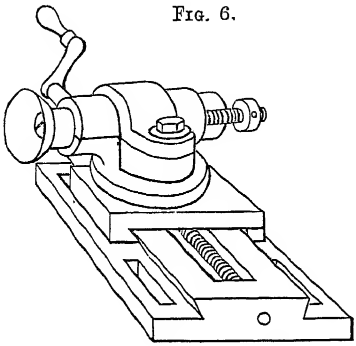
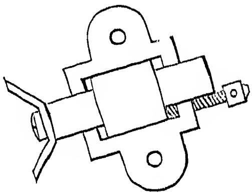


Fig. 7.



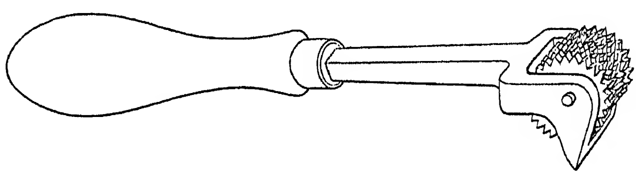
temporarily bolted down across the end of the frame of the grindstone to be turned, has a slide upon its upper surface moved by a screw and winch handle, and a box on the top plate which carries the cylindrical stem of the tool at a horizontal angle of about 20° to the length of the slide. The stem is enlarged about the middle of its length, as shown in plan with the cover of the box removed, fig. 7, and is moderately gripped in its bearings by the screws of the cover and does not revolve; it is pushed forward to place the tool in contact with the stone by a screw from the rear bearing against the back shoulder of its enlarged portion, and as it stands at an angle one side of the cup alone touches the stone and does the work.

The short hollow cones employed for turning grindstones are struck up from sheet steel of about one sixteenth of an inch in thickness, and are from three to four inches at their largest diameter, with their sides at an angle of 35° measured from the face; they are used unhardened, but are frequently stiffened by a similar but worn-out cone placed within and fixed with them on the pivot upon which they turn. The grindstones may be turned true wet or dry, and in the former

case with the entire absence of the clouds of gritty dust which accompany the use of the iron or steel turning bar.

The cup is also otherwise mounted in the manner shown fig. 12, and so that the tool is in contact with the stone throughout. Two supports carry a cylindrical main slide by any part of its length according to the width of the frame of the grindstone to which they are temporarily attached, and this cylinder is slotted on the under side to receive a corresponding strong feather in its cross-slide to retain the latter horizontal. The cup spindle is of the same form and is advanced in the same manner as previously described, but it stands square across the transverse slide at right angles to the axis of the grindstone; a pivot head with its cylindrical base much thicker on the one than on its other side is mounted to turn stiffly on the reduced end of the spindle, whilst the cup tool turns freely on its pin at an angle to the axis of the latter. One side of the annular face of the cup as before, therefore, only is in action, and at the termination of its traverse across the grindstone the pivot head is turned half-way round on the spindle which places the other side of the edge of the tool in contact for the return journey.

FIG. 8.



Other varieties of revolving discs have been used for the same purpose, among them the hand tool fig. 8, contrived by Mr. Charles Marlow, whose ingenious apparatus for glass facetting is described later. Fig. 8 consists of six or seven hardened steel discs one and a quarter inches diameter and one eighth of an inch thick, cut with saw teeth, mounted to revolve side by side on a spindle in a frame handle like a collection of coarse milling tools; and the under side of the frame is turned down as a fulcrum with a sharp edge, to prevent the tool from slipping when applied on the ordinary tool rest of the grindstone upon which it is used. The wheels are also mounted in

stems which may be clamped in the slide rest. The tool is quite successful and rapidly nibbles away the material in small chips or flakes, but it appears essential to its action for the discs to have a free lateral play within the frame, for them to rattle about sideways upon their spindle; the stone may be turned wet or dry. Grindstones are also turned after the same manner by a collection of such small steel discs, their total width about that of the stone, revolving side by side on a spindle supported on a base temporarily attached to the frame, arranged that the spindle may be advanced towards the edge of the grindstone and shifted from point to point across it.

The flat side of the stone is but little used for grinding notwithstanding that its broad surface appears so suitable for the purpose, but which is certainly not the case; first the spindle would be found to be in the way of large tools or their handles, and secondly, the constant reduction of the stone arising from the friction of the work rubbing away its granular particles, would soon cause the flat surface to degenerate into an imperfect cone and would leave a hump in the center, or if the stone were kept perfectly flat, it would be at the expense of its thickness, and the wedges by which it was at first secured would be gradually exposed and loosened.

The stone is turned either to or from the operator according to circumstances, and in all practical cases it is best that it should run towards the extreme edge of the tool and not from it, as in the latter case the last portion bends away from the stone and leaves a film or wire edge upon the tool, which the reverse direction avoids. The edges of the tools should be always ground parallel with the axis of the stone, or *transversely*, and not in the direction of their length, as the former position makes their edges concave to the same radius as the stone, and therefore keener and better prepared for the action of the oilstone.

In grinding the *ends* of rectilinear tools the stone should run towards the operator, as in turning, and for their *side* edges, it is perhaps the most convenient that the stone should travel the reverse way or backwards. Pointed tools are ground much

the same as flat tools, but the choice of method is in some respects a matter of personal convenience.

In grinding the bevils and edges of instruments in their manufacture, the workman is seated on a board called the *horse*, and generally rests his elbows on his knees for steadiness, as explained on page 127. The work is mostly applied to the stone by the hands alone without the employment, except in rare cases, of any guide beyond the sense of touch, which some of these workmen possess very acutely, and the amateur will find it desirable and sometimes imperative to trust to the feel alone in holding the tool upon the grindstone.

To grind the various tools with an uniform bevil requires some practice, as the least variation or tremor of the hand makes a corresponding irregularity in the bevil, after a time however the fingers acquire considerable sensibility and readily appreciate when the tool lies fair and flat upon the stone. In some cases the tools are applied upon a guide block that bears the same relation to the periphery of the stone that should exist between the respective bevils and faces of the tools, that is, if the edge of a tool is required to be exactly at right angles to the broad surface of the same, the plane or face of the guide upon which it is applied, should point directly to the axis of the stone, or be as a radius. If the edge should differ 10 or 20 degrees from the right angle, the rest is inclined upwards or downwards to the same angle. There are also instruments in which the rectilinear tool is grasped, so that the end to be ground forms with the two legs of the instrument a triangular base, the feet are applied to some fixed plane surface, and the tool or the third leg rests upon the grinding surface. These instruments will be described in Chapter III.

Two forms of apparatus in which the above-mentioned guide blocks are applied to the ordinary grindstone, were patented by Mr. A. F. G. Brown, of Glasgow, in 1883. In the one fig. 9, a quadrant of the grindstone is encaged between four or five pairs of rigid iron bars, which radiate from its axis like the spokes of a carriage wheel, but stop somewhat short of its periphery. The tool rests, across the edge of the stone, connect the ends of the pairs of bars and are formed

like three sides of parallelograms, of which the longer limbs slide on the radial bars and fix to them with bolts and nuts, to accommodate the reduction by wear in the diameter of the stone. The upper surfaces of all the tool rests are wide and flat, and stand in the horizontal plane in both directions; hence it is only necessary to press forward the tool with its shaft maintained in surface contact with the rest used, to ensure that the entire cutting edge is ground to a uniform bevil, provided always, that the stone itself is kept fairly cylindrical and in good order. The lowest tool rest, which is also about radial, serves for grinding tools for brass, and the others, in ascending order, for grinding tools for iron, steel and wood, and the uppermost gives the suitable angle for chisels and plane irons. The permanent position of every tool rest prevents the possibility of mistake as to the angle sought, no small advantage in workshop use.

FIG. 9.

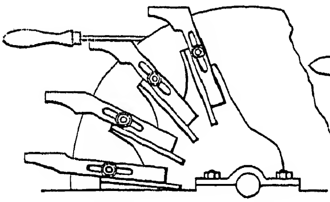
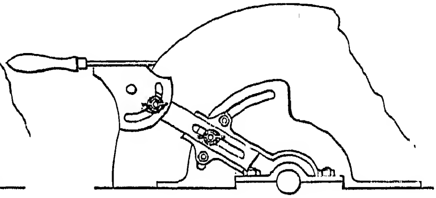


FIG. 10.



In the alternative form fig. 10, there is only one pair of elongating arms, which may be fixed at various elevations upon quadrants attached to the grindstone frame; the extremities of these arms carry the transverse tool rest pivotted upon them, the rest itself being made in one solid with two graduated quadrants by which its wide flat upper surface may be placed and fixed horizontally or to the various angles required.

The late Rev. Henry Lee-Warner, an amateur, constructed and patented in 1889 a simple apparatus to attain the same objects, arranged in a form to readily attach to the surface of the wooden bearers of an ordinary grindstone. An open cast-iron frame with triangular sides connected by cross-pieces below, fig. 11, is bolted down on the bearers, and the tool rest is fixed on the edges of its sloping sides by bolts working in

slots, at the different heights to give the various angles required in grinding. The frame is also adjustable by like means horizontally, to place the tool rest close to the periphery of the grindstone as that becomes reduced by wear.

A more comprehensive apparatus for grinding straight and angular edged tools to true forms and definite angles throughout the length of their cutting bevils, made by the writer, has a plain horizontal slide fixed on the surface of the frame parallel with the axis of the grindstone, the top plate of which

Fig. 11.

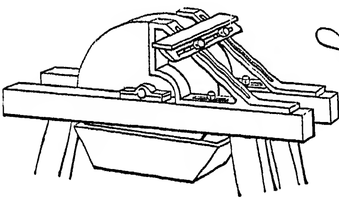
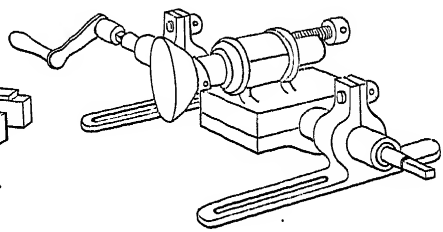


Fig. 12.



may be freely traversed to and fro along it by hand, so as to pass the tool completely across the stone whilst grinding. A short screw slide at right angles to the slide below, fixed on this top plate, brings the tool into first contact with the stone, and then gives it the necessary intermittent advances during the grinding; the tool holder is mounted on the top plate of this second slide, pivotted at one side, so that its surface may be raised or lowered to vertical angles to present the tool radially to the axis of the stone to grind the edge to 90° for cutting brass, and thence to all the more acute angles required for turning iron, hard wood and soft wood, the appropriate slope of the tool holder being read by a graduated quadrant at one side. The support of the tool holder also turns on a vertical pivot and may be fixed by its worm wheel and tangent screw, to present the shaft of the tool at horizontal angles for grinding the side edges of point tools, etc.; and the traverse of the plain slide is sometimes made automatic by connecting it with the revolutions of the spindle of the grindstone.

The broad flat surfaces of the forgings of chisels and other tools which are ground to produce their superficies are traversed quickly to and fro upon the *top* of the grindstone, as

a short period of rest would grind a hollow place of the same curvature as the edge of the stone, and it is to lessen this evil as far as possible that the largest stones are employed for saws, the sides of which are required to be flat and parallel. In the razor on the other hand the curvature is desirable, and the four inch stone is there the nominal desideratum, and still smaller grindstones are very often employed.

The following examples of the mode of grinding a few of the most usual tools for wood and metal, will explain the methods generally pursued by artizans, which differ from the practices of the cutler and grinder only so far as is called for by the nature of their respective apparatus.

In grinding an ordinary plane iron the grindstone travels towards the operator, and the tool is applied about half way up the stone from the axis, the rest is not generally used, but the iron is grasped firmly in the right hand to guide it, the position of the hands being the same as that for sharpening the tool explained in page 206 while the pressure is principally given with the fingers of the left hand applied near the edge of the blade. The iron is inclined vertically so that the chamfer may be ground to the angle of about 25 degrees with the face of the blade, but horizontally the iron should be held quite square to the face of the stone, or parallel with its axis, in order to prevent either corner being reduced below the proper line. To assist the inexperienced in determining when the plane iron is held square, the top iron is sometimes kept on during the grinding, but it is set back about one eighth of an inch from the edge so as to be quite out of the reach of the grindstone, as the action of the top iron would be materially injured or altogether spoiled, if its form were interfered with, it is however a safer and more cleanly method to remove the top iron before grinding.

To assist in keeping the arms steady, they are pressed firmly to the sides of the body as far as the elbows; and to traverse the tool across the face of the stone, the workman swings bodily from side to side without moving his feet, so as to shift the tool gradually and almost constantly without disturbing the position of the arms, which would be liable to

grind a second facet upon the bevil of the tool, or otherwise to grind the edge rounding instead of in a right line. The grinding should be continued until nearly the whole of the bevil made in the sharpening on the oilstone has been removed, but unless the iron be notched it is advisable to avoid grinding it to an absolute edge, which would be liable to produce a wiry film, the removal of which is troublesome.

To ensure the bevil being ground flat, it is in all cases necessary that the tool should be held at the same angle throughout, and also that the edge of the tool should be continuously applied at the same height above the axis of the grindstone. Should the edge of the tool be shifted a little upwards during the grinding, a second facet would be ground somewhat more acutely, and if shifted downwards another facet somewhat more obtusely; the combination of the two movements would produce a rounded instead of a flat chamfer, whereas if the tool be held steadily and as nearly as possible at the same position throughout, the chamfer will be ground slightly concave, from the circular form of the stone, which is desirable in tools for wood as they then cut more keenly.

Carpenters' chisels are ground in exactly the same manner as plane irons, but chisels below about half an inch wide are more difficult to grind square, as an oblique position of the shaft of the tool in plan, is not so readily detected in such narrow tools.

Carpenters' gouges are ground in the same manner as chisels, except that while the fingers of the left hand are held quite steady to give the requisite pressure, the tool is rotated in the right hand, backwards and forwards in an arc of about one third of a circle, much the same as in boring a hole with a bradawl. Gouges that are sharpened from the inside do not admit of being ground on a flat stone, they are therefore in general thinned with a slip of gritstone in the same manner as the moulding plane irons explained in the next paragraph.

Moulding plane irons are not generally ground because from their complicated forms they would require grindstones fashioned expressly to suit nearly every kind, but preparatory to sharpening with the oilstone slip, the bulk of the material is removed either with files, or narrow slips of gritstone applied in much the same manner as the file. The irons of

moulding planes like those of ordinary planes are always made principally of iron, with a thin facing of steel to constitute the cutting edge, the file may therefore be successfully applied to remove the bulk of the iron, leaving little more than the thin steel edge to be abraded by the oilstone slip. As mentioned at page 493 of Vol. II. care is required in restoring the edges of moulding plane irons to keep the figure of the cutter in the proper position to fit the plane. Concave plane irons may be successfully ground on the conical grinders employed for concave turning tools, referred to in the succeeding chapter.

The soft wood turning chisel is ground with two bevils meeting at an angle of from 25 to 40 degrees as explained on page 513 of Vol. II. and as there shown the edge is placed obliquely at an angle of about 25 degrees. In grinding this chisel the stone should revolve towards the edge of the tool and the rest is not generally employed; for the one bevil the handle is grasped with the right hand, whilst the pressure is applied with the fingers of the left, much the same as in grinding the plane iron, but the shaft of the chisel must be held at an angle in order to place the edge square upon the grindstone. When the chisel is turned over to grind the second bevil, the angle at which the shaft is held is reversed, and also the position of the hands, the left then grasping the handle and the right supplying the pressure. As in the plane iron it is desirable not to grind the tool quite to an edge, but to leave a narrow line of the facet produced in sharpening.

In grinding a turning gouge, which requires to have an elliptical edge as noticed on page 512 Vol. II. the stone generally travels from the operator. The tool is held after the same manner as a turning chisel, except that the oblique position of the shaft is uncalled for, and to give the elliptical form to the edge the gouge is twisted in the hand half a turn backwards and forwards, and it is at the same time traversed across the face of the stone, not in a straight line against the rest, as for most rectilinear tools, but out of contact with the support, and in a semicircular path like an inverted arch, the sides of the gouge being applied nearer to the top of the stone than the middle of the gouge; a few trials will render this action familiar.

Flat tools for turning hard wood, ivory, and steel are ground with the stone running towards the operator, and the tool is applied face upwards on the rest, inclined vertically to the suitable angle for the edge, which is generally from 60 to 80 degrees, but flat tools and chisels must be held square horizontally to avoid producing oblique edges. The handle of the tool is grasped in the right hand whilst the fingers of the left applied near the edge serve to steady the tool, which is gradually traversed across the face of the stone, but to keep the edge straight care must be taken that both hands are moved equally, or parallel with the axis of the stone, otherwise the edge of the tool will become rounded. Flat tools for brass are ground in the same manner as the above, except that the vertical inclination is not required, and the tool is pointed to the axis of the stone as in turning a cylinder.

It should also be noticed that the straight cutting ends of all flat tools, as seen from the face of the tool, are not ground absolutely square across at right angles to the length of the shaft but at a small inclination of two or three degrees to it, and so that the left-hand end of this cutting edge meets the side cutting edge of the tool at an angle a little less than 90 degrees. This which may be seen rather exaggerated in the explanatory diagram, fig. 416 Vol. IV., is required to permit the use of the flat tool in correcting and finishing the turning of a rebate or fitting, so that the side cutting edge may travel along or down the surface half of the rebate quite into the corner without the end cutting edge touching the cylindrical half and, in like manner, that its end edge may be used upon the cylinder without the side edge acting upon the surface, so as to produce the true internal angle of 90 degrees in the work.

Right and left side tools are most conveniently ground with the stone running backwards, and the tool is applied at the top of the stone with its face or upper surface towards the operator, and its shaft parallel with the axis of the stone, the tool being inclined backwards in order to give the required bevil. For grinding the end, the stone travels forwards as usual, and the tool is applied on the rest as in grinding a flat tool.

Triangular tools that are required to cut very keenly, are ground in the same manner as the side tools, by which the

edges are made slightly concave; but when the triangular tool is required to be less penetrative and more durable, it is applied on the top of the stone at right angles to its axis, and traversed quickly backwards and forwards as in grinding a flat surface.

Square tools for turning brass are ground in the same manner as triangular tools.

A graver is held point upwards on the rest, with the stone running towards the operator, and it is best to remove the extreme point by grinding a minute triangular facet at right angles to the principal chamfer, but less in size than a pin's head, the tool performs as well, and the point is considerably strengthened; it requires only a touch on the stone. Many of the tools for metal are used at once from the grindstone, which could not be the case if a film were left upon them, as explained at page 166.

Point tools are ground in the same manner as flat tools, except that the tool is held horizontally at the suitable angles for the point.

Large pointed drills that cut in the one direction only are ground the same as point tools, except that for the second edge the drill is turned over and applied at the same angle as for the first edge. Small pointed drills that cut in both directions are generally sharpened on the oilstone without grinding. When the latter process is resorted to, however, the tool is held like a pen near the top of the stone, which runs backwards.

Twist drills require more care as it is necessary to grind both of the conical surfaces which meet the spiral grooves and form their cutting edges, as nearly alike as possible in all particulars; this is done by hand on the grindstone and more exactly in machines, the practice followed for both methods is described in the next section.

Round tools are held upon the rest much the same as flat tools, except that they are not traversed in a line across the stone, but while the extremity of the tool is kept nearly stationary, the handle is moved horizontally through a semi-circle around the part of the tool supported on the rest, which serves as the imaginary axis.

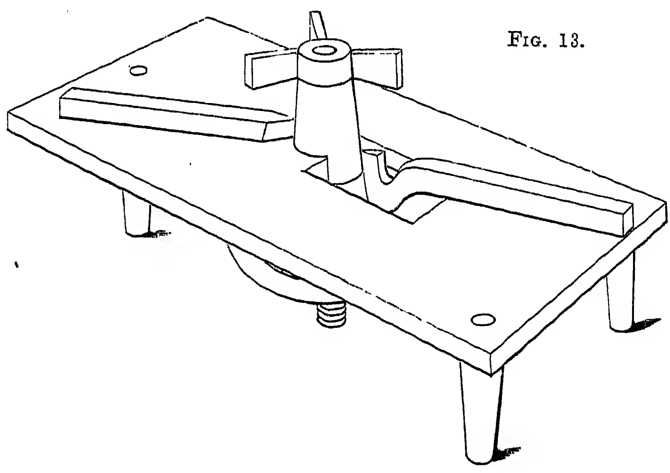
Round tools that are much bevilled are sometimes ground in a manner similar to the gouge, but without the rotation on

the axis of the tool therein called for. Mechanical means of grinding the edges of some round tools to exact semicircles and of determined radii are described in the following chapter.

Heel tools for turning iron are supported upon the rest exactly in the position for turning, shown in figs. 415 and 417, page 525, Vol. II., but the handle is a little more depressed to place the bevil at the suitable angle, and the tool is swept round in a semicircle like the round tools, the point of the heel serving as the axis of rotation.

Slide rest tools for metal turning are generally held upon the rest, and as they are mostly used direct from the grindstone without having recourse to the oilstone, it is desirable in all possible cases that the stone should run towards the edge. They are applied to the grindstone after the same general method as the hand tools of corresponding forms, but as explained in pages 530 to 534 of Vol. II., the fixed tools require additional care to preserve the proper angles for cutting, and the simple tool-gage, figs. 438 and 439, Vol. II., may with advantage be resorted to for determining the angle of relief.

FIG. 13.



A still better form of Mr. Nasmyth's above-named tool-gage, fig. 13, which shows at a glance whether the tools have been ground to their correct cutting and relief angles, has been made by the writer to the design of Lord Blythswood. The instrument has a truly surfaced iron table, standing on

three legs, countersunk in the centre to receive the base of the cone, which tapers 4° to give the angle of relief; and the cone is raised or lowered to bring the cutting angle gage above it in contact with the face of the tool, according to the thickness of the stem of the latter, by a screw and hand wheel, seen below. The stem of the cone has a feather to prevent its turning round, and the cutting angle gage, pivotted to turn upon its axis above, has three arms the under edges of which give the correct angles for brass, iron, and steel. The tool in process of grinding is laid on the table and its end tried in contact with the cone; when these are found to agree, the cone is lowered until the cutting angle gage touches and determines the correctness or otherwise of the facial angle; tools with straight stems may be applied from any direction, and an oblong aperture which extends under the base of the cone is pierced through the table, and permits the verification of the angles of those with curved and crank-formed stems.

Detached cutters for fitting into cutter bars, such as those shewn in figs. 440 to 442, page 535, Vol. II., and those of the gouge cutter bar, page 143, Vol. IV., cannot be conveniently ground whilst in the stems in which they are held in the sliderest, and if detached they are too small to be held in the fingers, they are therefore fixed in socket handles of appropriate forms, or otherwise they are grasped in a hand-vice, which serves as the temporary handle for applying them to the grindstone.

Screw tools and moulding tools used by hand, that are cut to their respective forms on steel hobs or cutters, as explained on page 591, Vol. II., are sharpened only upon their upper surfaces as the forms of the tools would be impaired by grinding their ends. They are frequently sloped off on the face, and this method serves sufficiently well for tools applied to the hardwoods and ivory, but as explained on page 520, Vol. II., the slope increases the angle of the edge; and the method of nicking in the tools, shown in fig. 407, by applying them transversely on the grindstone, is far preferable for screw tools intended for iron and steel.

The preceding section on the manipulation of the grindstone may be followed by a notice of an interesting process in

every respect dissimilar, and only remotely connected by the circumstance that the grit, used in a compact mass in the grindstone, is again the cutting agent, but in the disintegrated form of sand. The attrition from sand rubbed between the work and some form of revolving or reciprocating tool has always been employed for cutting, grinding, and polishing glass and stone,—as described in following chapters,—but the use of sand alone, simply directed on the work, is met with in the ingenious Sand Blast Process, patented by Mr. B. C. Tilghman, and is comparatively recent.

In this process a stream of sand, dry or mixed with water, is forcibly projected on the work upon which the little particles act with surprising vigour, abrading or cutting it by their impact alone. It is employed upon metal, stone, and glass; its principal applications upon metal are for eroding surface decoration, and to hardened steel for the so-called sharpening of files. A description of the apparatus used for the latter follows, and the application of the sand blast to embossing or engraving glass and other materials will be noticed in later pages.

In the manufacture of files the teeth are formed partly by the burr raised or driven up by, and partly by the cuts or indentations made in the surface of the blank with wide sharp chisels of the peculiar form shewn by fig. 14,—reproduced from the illustrations, page 828, Vol. II.—where also the whole method is described. A parallel series of angular furrows is first struck with these chisels, close together and diagonally across the blank, called the first course, followed by a second similar series placed at a small angle to the first, called the second course; and this leaves the file covered with triangular points or teeth of the shape shewn edgewise and enlarged, fig. 15, after which the file is hardened.

The file pushed forwards upon the work in the direction of the arrow, cuts by the extreme points of the teeth, these gradually lose their original keenness and wear away until they will no longer "*bite*" the work. In practice, it may be said, a new file is if possible first used upon brass or gunmetal, because these materials not only require the file to be in its best and keenest condition, but also because the wear or deterioration they cause to its teeth is comparatively

moderate, so that the file, when a little worn as regards these materials, may subsequently be used on iron without very sensible loss of effect of its cutting powers; finally, the teeth gradually wear down into flats, indicated by fig. 16, when the file can no longer cut and is worn out. The larger files when in this condition are sometimes softened, reground and recut, but as the teeth must be completely ground out before recutting they suffer appreciable loss of substance.

Fig. 14.

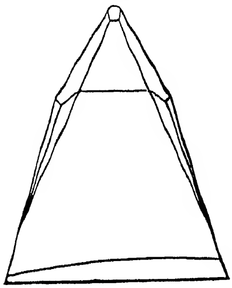


Fig. 15.

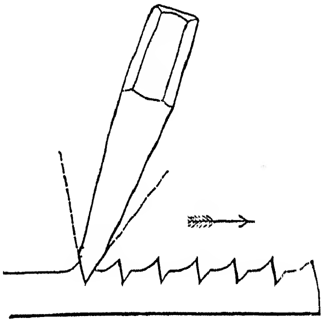


Fig. 16.

Fig. 17.

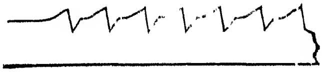
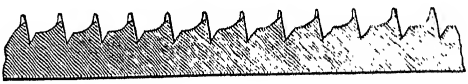


Fig. 18.



The sand blast was originally and successfully applied to resharpen worn files, to maintain their thickness, and as an inexpensive substitute for recutting. The stream of sand and water projected on the file from tang to point, wears away the curved or burr sides of the teeth until these again meet the upright or indented sides, which it cannot touch, and at an angle that is but little less keen, fig. 17, than that given by the original cutting. The files resharpened in this manner and used in the writer's workshops, prove quite satisfactory for iron, but not for brass and gunmetal; their failure upon the latter being evidently due to the small increase in the

angle of the teeth, and the consequent loss of keenness necessary to these materials, as mentioned above.

The method by which the sand blast is produced will be recognized in the well-known spray disperser, fig. 19. This little toilet instrument is formed of two glass tubes reduced to small orifices at their converging ends, and sliding within a bracket to place the aperture of the vertical tube in contiguity and across the diameter of the orifice of the other. When the lower end of the vertical tube is sealed by the liquid, air blown through its horizontal companion causes an updraught, and

FIG. 19.

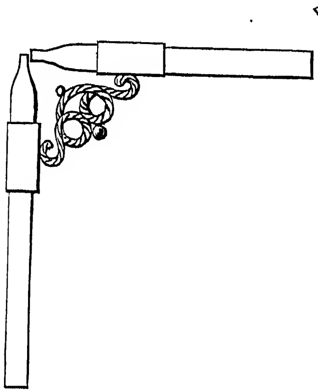
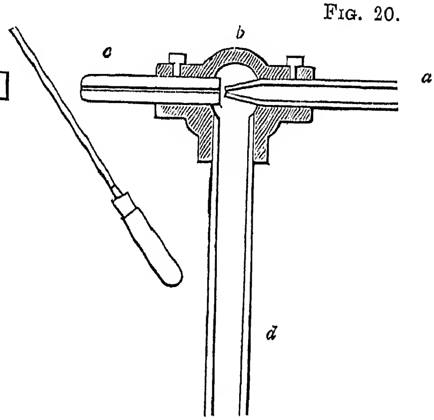


FIG. 20.



the fluid is continuously sucked up and simultaneously dispersed in spray as it issues from the orifice.

The original form of the sand blast delivery pipe is shewn in section fig. 20. A steam pipe *a*, its end contracted by a conical bore to a quarter of an inch aperture is held in the head or tee piece *b*, the opposite arm of which carries the nozzle *c*, a parallel iron tube of half an inch bore. The ends of the two tubes are a little separated, and the bore of the connecting head *b*, is enlarged all around them to afford space for the sand and water which arrives up the vertical pipe *d*, opening into this enlargement. The jet of steam issuing from *a*, at about 60 lbs. pressure, sucks up the sand and water and at the same time projects it along *c*; the remaining portions of the apparatus are mentioned later. The analogy to fig. 19 is complete, but fig. 20 is made in three pieces for

adjustment and for renewal of those which wear out; the principal wear takes place in *c*, and is greatly accelerated should its bore be otherwise than precisely central with that of the steam pipe. The file held in the hand at an angle, is slowly traversed from tang to point across the orifice of *c*, and the stream of sand forcibly falling on the burr sides of the teeth only, rapidly reduces these until their curvature again meets the upright sides and the flats disappear.

Minute examination of new files shows that the upright faces of the teeth do not invariably continue absolutely flat up to the point where they meet the burr sides, but are themselves often slightly rounded over at the tops, as shown in an exaggerated form by fig. 18. Theoretically, and to a small extent practically, this is objectionable, and a brief subjection to the sand blast, only just sufficient to remove these possible minute curvatures, is frequently given to new files, which are considered by some to be much improved thereby. The apparatus employed for this purpose, and for re-sharpening old files, has two blasts which operate upon two or upon all four sides of the file at the same time. These also deliver the sand and water in a thin flat in place of a round stream, which is found to act more uniformly over the surfaces.

The working parts of the apparatus, indicated by fig. 21, are as follows. The two round steam pipes *a*, *a*, terminate in flat, hollow, tee-shaped cross pieces, the front and solid portions of which are pierced with a row of five or six conical holes, about the fifth of an inch in diameter on the nozzle side, and gradually enlarged backwards until their edges meet on the side by which the steam enters them. The nozzles *b*, *b*, are each formed of two halves, like the four sides of an oblong box, and are clamped against and in front of the pierced faces of the tee pieces; their orifices for the delivery of the sand, narrow slits in front, are enlarged and hollowed out behind all around the orifices of the steam holes, to form a space to receive the sand and water drawn up by the force of the steam jets through the pipes *c*, *c*, from the vessel *d*, below. These parts are capable of adjustment, so as to place the central line of the aperture of the nozzle in precise agreement with that of the row of steam holes at its rear end, necessary, as before mentioned, to prevent unequal wear. The pipes *c*, *c*, descend

and draw their supply from the bottom of the tank *d*, the conical shape of which latter causes the sand to settle to yield a uniform quantity. The two converging sand blasts inclined vertically as shewn, are fixed in the other direction at a small horizontal angle to one another, and deliver their jets of sand and steam in front of an aperture in the end of a box with a sloping bottom, from which the sand and water flows back through a sieve to the tank to be used again. The file held

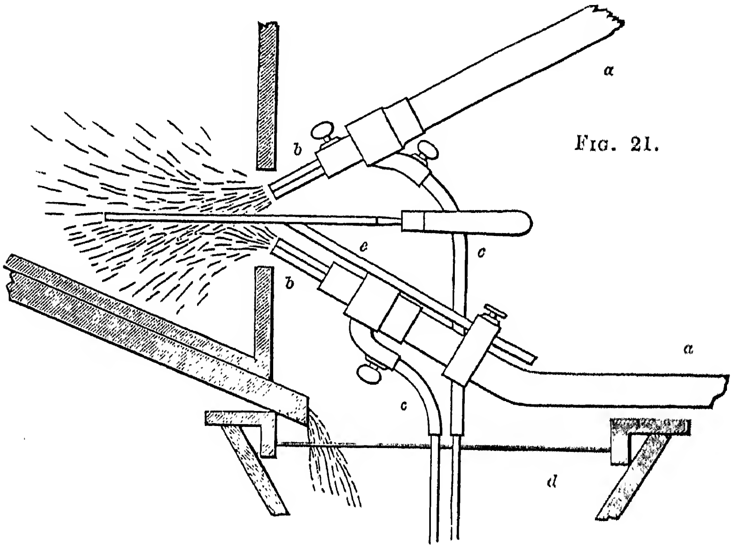


FIG. 21.

by its tang in a temporary handle is thrust through the aperture in the box, and gently drawn back between the blasts towards the operator; and in the case of a flat or square file, the spreading commingling sand blasts take effect upon all its four sides at the same time. Throughout the process the file rests and is drawn back upon the end of a piece of brass, *e*, of rather more than its width, attached to the lower steam pipe, and called the *feeling piece;* the point of contact between the two is just in rear of the sand streams, and by the sense of touch felt in the equal hang of the file to this test piece, the operator is able to ensure that the blast produces a uniform effect from end to end of the file.

The sand blast has also recently been employed for roughening the edges of grindstones and emery wheels used for

fettling castings and other rough work, to remove the particles of metal with which they become clogged. In the machines constructed by M. N. Kahn of Paris, the stream of sand or emery is projected by compressed air through a vertical pipe within a rectangular funnel-shaped cast-iron casing, of considerably greater length than width, within which latter the stone or emery wheel operated upon slowly revolves. The large oblong upper aperture of the funnel is closed first by the stone, the spindle of which is lowered until its periphery just about fits the long diameter, and then by two adjustable top plates which are advanced laterally to touch the sides of the stone, and the sand or emery, of which little escapes, after striking the edge of the grindstone, falls back to the base of the funnel.

SECT. II.—GRINDING CUTTING TOOLS AND DRILLS ON FACTITIOUS GRINDSTONES AND EMERY WHEELS.

The artificial grindstones used for the above purpose and described as to their composition and manufacture in the preceding Catalogue, are of three principal varieties, viz., of Corundum combined with shell lac, or with lime, cement, and silicate of soda; of Emery of various degrees of coarseness for different qualities of wheels, combined with Portland cement, lime, etc., and silicate of soda; and of natural Sand cemented together after a similar manner. The last named artificial grindstones—described under the head of Wheels, article 33, are of excellent quality and differ but little from the natural gritstones in their properties, use or appearance, whilst their mounting and manipulation are precisely the same; these, therefore, do not require further notice.

Corundum wheels do not usually exceed about four inches in diameter or about half an inch in thickness, and they have knife edge, flat, rounded and other shaped edges. The smaller from three quarters of an inch to two inches diameter, mounted and driven in small foot lathes, are extensively used in mechanical dentistry—see Wheels, article 34. Corundum wheels are perhaps less employed than they deserve for grinding the forms and edges of cutting tools, to the smaller of which their quick yet fine grinding action and their capacity

for retaining the shapes of their peripheries render them particularly suitable. Among other purposes the small round edged wheels are adapted to grinding out the long channels of shell and spoon bits and analogous tools, and especially for the narrow deep cavities of the smaller gouges used by the wood carver, in which the internal curvatures are too often irregular; the wheels with angular edges apply in like manner to the angularly grooved tools, such as the soft wood turners and wood carvers parting tools, to which they give the requisite well defined internal angles with much precision.

Small corundum wheels with semicircular edges in a series of gradually increasing widths from about one sixteenth of an inch upwards, are useful for re-shaping and sharpening the cavities and the concave portions of the edges of hand bead tools, and of the various small bead and moulding slide-rest tools, drills and cutters used in ornamental turning, tools figured and described in Volumes IV. and V.; and various other modes of sharpening these tools follow in the present Chapter. These miniature grindstones for grinding and sharpening the above-named small tools are sometimes mounted every one separately upon a stem to fit in the head of the apparatus, fig. 74, or upon arbors fixed in a chuck to screw on the lathe mandrel, or else upon spindles to run between the lathe centers, the particular arrangement adopted being immaterial.

The bead and other tools for plain hand turning fixed in their permanent handles, figs. 395—399, Vol. IV., and the slide-rest tools figured on pages 60 and 61, Vol. V., placed in the socket handle, fig. 18, Vol. V., and the corresponding drills and cutters in their appropriate holders, figs. 66, 67, with these holders in the socket handle, firmly held face upwards and close to their cutting ends between the thumb and the two first fingers of the right hand, the thumb on the face of the tool and the wrist flexible, are applied with moderate pressure on the top of the corundum wheel which is moistened with oil and runs away from the operator towards the cutting edge. The shaft of the tool is held sloped at the appropriate inclination to give the cutting angle, and in this position the overhanging weight of the handle materially assists to maintain the tool at the same inclination throughout,

and thereby to grind the edge to one uniform bevil. The tools may very frequently be used direct from the corundum wheels, or if a still finer edge be desirable, they may then be further finished upon the little cone grinders mentioned in a later section; sharpening first with the one and then with the second method will be found more expeditious than using the latter alone, especially for tools in bad order.

Emery wheels, the second variety of artificial grindstones,—see Emery, article 12, and Wheels, article 34,—introduced originally for the purposes considered in this section, have for many years steadily gained in favor with consequent increased application, until, at the present time, it would be difficult to assign limits to their use. Some are mounted after the manner of the ordinary grindstones and are employed for cleaning and shaping castings and forgings, for general rough grinding, and for grinding the edges of cutting tools; these last will be described in this place. Secondly, they are largely used in more or less elaborate machines, the other parts of which carry and usually move the work against the revolving wheel; under which conditions they aid and in some cases replace the file, planing machine and turning tool for the production of much plane and other surface work, simple and complex solids, fluting, grooving, etc., in brass, iron, and steel. Some typical examples of these emery grinding machines will be described in following Chapters.

The smaller emery wheels for workshop tool grinding are usually mounted after the manner of fig. 22. The wheel of about 12 inches diameter by one to two inches in thickness, is attached to the end of a spindle in the manner hereafter described, which runs in bearings on the top of a cast-iron base; the opposite end of the spindle carries a small pulley for the driving band, which is led to it preferably from below, or from above if that be more favourable to the driving arrangements of the workshop. The base is fixed down to a cast-iron rectangular drip tray, which latter stands upon spreading legs for an independent machine, or when several such machines are employed, the trays are bolted down side by side upon a long bench or other bearers with one driving shaft for the whole series. Sometimes both ends of the

spindles carry emery wheels, which may be of different shaped edges, or degrees of coarseness, the one to commence and the other to finish the grinding; the driving pulley is then placed midway on the spindle between its bearings. The support for the tool stands on a bracket cast or bolted on to the sloping sides of the base and is of precisely the same form as the ordinary hand rest of a lathe, adjustable, therefore, both vertically and horizontally; sometimes it is simply a piece of cast-iron or a bar bent at right angles, which is less convenient. The upper surface of the tee shown is

FIG. 22.

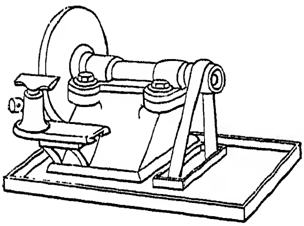
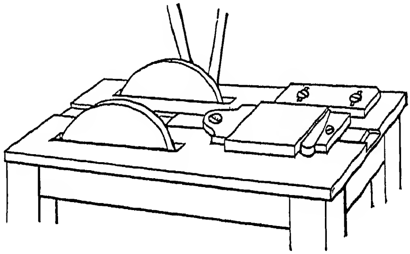


FIG. 23.



usually flat and the tool to be ground is tilted up upon its edge to the required angle; but these surfaces may be both wide and to stand at appropriate angles to the horizontal plane, that when the shaft of the tool is held down in contact with them, they may serve to present and grind its cutting end to the requisite angles for different materials, after the same manner as the grindstone rests already described, fig. 9.

The emery wheel in fig. 22 is driven at about 1200 revolutions per minute and may be used dry or with water. The shafts of tools and other moderate sized objects that can be held in the fingers, or presented to the wheel held on a flat piece of wood, are ground to shape lengthwise as to their surfaces traversed to and fro with moderate pressure on the top of the wheel, and the work is dipped in water from time to time when it becomes inconveniently hot. The cutting edges of tools are ground in the same general manner as on the ordinary grindstone, but with less pressure, to prevent the more actively cutting and rapidly revolving wheel from heating

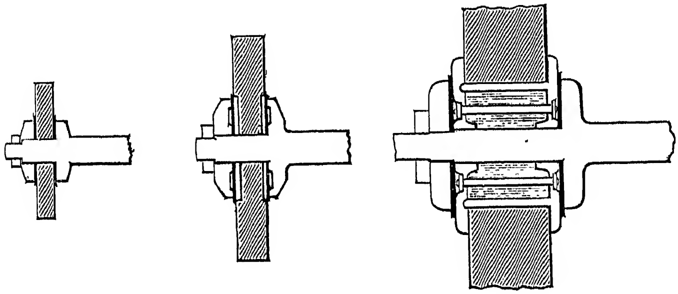
and reducing the temper of the steel; to this end also a more plentiful supply of water is employed and allowed to fall on the wheel close to, or indeed upon, the point of the tool.

The emery wheels generally used for grinding the edges of tools are of rather fine grain, made from emery crushed to a size that will pass through a sieve of about sixty apertures to the inch; these grind a smooth bevil and yet cut with sufficient rapidity with a moderate pressure. They are driven at the rate of about 3000 ft. surface speed per minute, the smaller wheels, therefore, run much faster than the larger; the full and economic effect of all emery wheels is only attained when they are driven at this high rate of velocity,—see Emery, article 12,—and for safety under these circumstances it is necessary that the frame and mountings should be strong and rigid, firmly fixed down, and that the wheel itself should be securely attached to its spindle and truly circular upon its edge. As precaution against the possibility of fracture of an unsound wheel from centrifugal force, however, all those of the best quality are tested before issue by being driven at more than twice the speed at which they will be subsequently used.

The round hole for the spindle is generally fairly true with the circumference and square or at right angles with the sides of the wheel, and the smaller and moderate sized wheels are usually mounted directly on their spindles in the manner shown by fig. 24. The spindle fits the aperture just easily, as the wheel must not bind upon it, but yet without shake, and the sides are held between a flange in the solid with the spindle on the one side and a stout washer of equal dimensions, brought up by a screw and nut, on the other, with a thin packing of millboard, leather, or other parallel and semi-elastic material interposed on both sides of the wheel. Large wheels are of necessity mounted with more care, and preferably so that the substance of the wheel itself is nowhere in actual contact with the spindle. In the method shown by fig. 25, strong circular iron plates with apertures accurately turned to fit the spindle, are embedded in the wheel during its manufacture, and these plates are held between flanges partially hollowed on their surfaces so as to grip the wheel close to the spindle and by their circumferences with the

packing interposed as before. A third method, fig. 26, is intended for the largest wheels to secure both truth of mounting and to economize material by dispensing with that portion of the emery wheel usually held between the flanges. A hollow cast-iron hub provided with a wide external rim or flange, passes through an emery ring and sufficiently for its projecting edge to enter an annular recess in a loose iron flange of the same dimensions as the rim on the hub; the two parts are held together by bolts to grip the emery ring, and are bored to fit the spindle, the whole being secured with the packing between the flanges on the latter.

FIG. 24. FIG. 25. FIG. 26.



Small fine grained emery wheels up to about eight inches in diameter are a fairly useful addition to the grinding apparatus of the amateur, who, however, is rarely in a position to drive them at the high speed at which they act the best. These are sometimes mounted on spindles similar to those for circular saws, fig. 734, Vol. II., to be used running between centers in the lathe. This practice is not advisable with lathes intended for the best purposes, and it is better to mount the spindle in a separate machine, fig. 5, where the particles of emery detached by use are less objectionable.

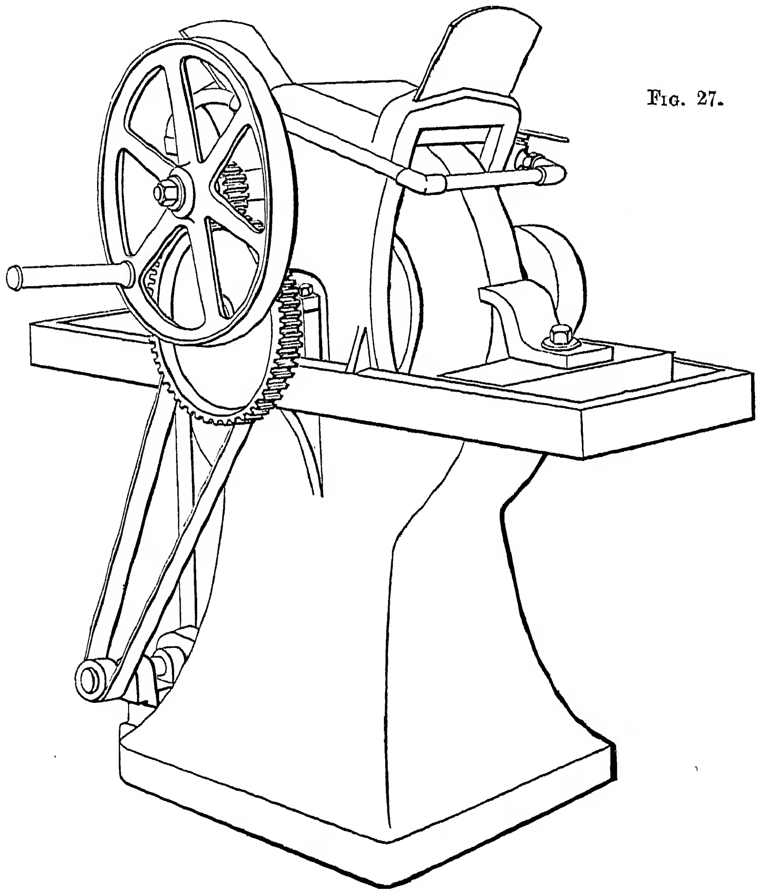
The smaller wheels are generally used as supplied, but the larger, when mounted, are first turned true upon the edge and partially down their sides whilst revolving on their spindles; an operation which should be repeated upon those of all dimensions, so soon as they commence to lose their circularity from use, requisite not only to deter the more rapid wear they suffer when out of truth, but to prevent the

possibility of one side of the wheel becoming heavier than the other, in which condition the want of perfect balance in the larger wheels, taken with their rapid revolution, soon becomes a source of danger. The wheels are turned true, wet or dry, with a morsel of black carbonate, see DIAMOND, article 7, and the tools, figs. 390—392, are used by hand, or in a sliderest to mount on the grinding frame after the manner of fig. 6. The diamond slightly projects from the blunt conical end of the round shaft of the tool used by hand; with this, flat edges are reduced cylindrical by abrading or turning them away as a series of rings or grooves merged into one another; rounded, angular, or other peripheries are turned after the same manner, and the partial rotation of the round stem of the tool upon the rest permits an edge or corner of the diamond to be more readily applied in those positions in which it cuts most freely. This quasi-turning tool necessarily requires rather careful manipulation to prevent the wheel from grinding away its somewhat slender setting and loosening the diamond. The tools used for the larger emery wheels have square stems to be clamped in the rest, by which they are gently and steadily traversed across the edge of the wheel. It is generally preferred to turn the wheels true when dry and revolving at a very moderate pace, and for the large tool grinding wheels shown by fig. 27, provision is made for a more considerable reduction of speed and the wheel is set in revolution by a hand motion. The revolving disc tools, fig. 6, are also sometimes used for turning emery wheels true, and also in the course of their manufacture, but this entails a rather rapid destruction of the chilled iron or hardened steel discs employed.

The engineer's large tool grinding wheel, fig. 27, has a disc or ring of emery of about two to three foot diameter, held and mounted on its steel spindle by the hub, fig. 26, and is driven by a pair of fast and loose pulleys on the spindle, partially seen in the drawing, at the rate of from 500 to 350 revolutions per minute, according to the diameter of the wheel. The opposite end of the spindle carries a large spur wheel with a pinion and hand fly wheel above, which, at other times removed, are temporarily placed in position to rotate the wheel when that has to be turned true. A tool rest at either side of the wheel, bolted down within a shallow oblong cast-

iron tray to catch the water, allows tools to be ground with the wheel running towards or away from their edges; and the wheel is enclosed within an iron hood with two adjustable plates to be lowered nearly in contact with it, also to catch the

Fig. 27.



water thrown off from its edge. The water flows down from the wheel and the tray into a reservoir within the base of the machine, whence it is raised and directed on the wheel and tool through external pipes terminating in a pipe with adjustable holes or nozzles, by a centrifugal pump set in motion by a strap from a small pulley on the spindle, hidden in fig. 27 by the spur wheel.

However strong the frames and mountings, it should be added that, it is of the utmost importance in results with all emery wheels whether used as simple grindstones or in machines for more accurate grinding, that their spindles, mountings, and all other revolving portions should be each individually accurately balanced. That is to say, and taking a toothed wheel or driving pulley as an example, such wheel when tested by being placed in independent revolution, should come to rest indifferently and not always with the same portion of its periphery at or about the same place; cast wheels very generally prove more or less out of balance, and require some reduction of material from the arms or rims on the heavy side to ensure their perfect equality of momentum. This quality is too frequently overlooked, but if attained throughout, the most rapidly revolving grinding machines not only run so free from vibration that they may even be used without bolting down, but they produce a far more uniform and finished surface on the work.

Twist drills which range from a sixteenth to three inches in diameter and are used principally for metal, but are also sometimes used in boring the hard woods, require exceptionally careful treatment in grinding their cutting edges. The drill is a round steel rod, fig. 29, fluted with two equidistantly placed spiral grooves, their opposing sides, *a*, *a*, viewed from the cutting end, fig. 28, the one a little above and the other a little below its axis; these sides, therefore, stand as tangents to a space in the central portion of the tool and this space called the web increases in its dimensions according to the magnitude of the drill. The shafts of the smaller twist drills are cylindrical throughout their length, the larger for a portion only from which they slightly taper to their butt ends; and in all, the tops of the ribs between the flutes are reduced all along their length, as indicated by the dotted lines, fig. 28, so as to leave only a small portion of their original circumferential section. Both these reductions, called *backing off*, are required to lessen the friction of the drill within the material in boring, and are made in its manufacture subsequently to the fluting,—the first with the flat edge of an emery wheel in

rapid revolution traversed along the drill rotating between centers, and the second with a face cutter or the face of a small emery wheel employed much after the manner of cutting a screw thread.

The cutting end is ground as a cone of about 60°, and not to the axis of the shaft of the tool, but each side or lip, that is, the ends of the ribs between the flutes, as portions of similar but distinct cones, their axes transverse to that of the drill and also slightly removed to either side of its plane; this leaves each of the straight cutting edges, *a*, *a*, formed at the ends of

Fig. 28.

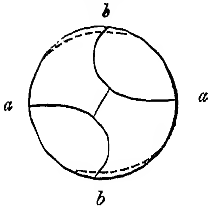


Fig. 29.

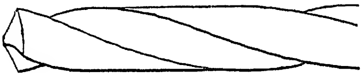
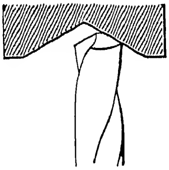


Fig. 30.



the two tangential sides of the grooves of the same length and angle, and the short line in which these two conically ground portions meet, fig. 28, diametrically across the end of the drill, at right angles to and precisely bisected by its axis. The divergence of the axes of the conically ground portions from that of the plane of the drill axis, also causes these conical surfaces to slope backwards about 10° to 15° from the straight cutting edges, *a*, *a*, to the outer edges of the opposite flutes at the circumference, *b*, *b*, which downward slope, also called backing off, gives the cutting edges their angle of relief.

Precise equality in the forms, positions and angles of the two lips, if it could be so effected, would be attained with a hollow grinder of the appropriate cone, by advancing the point of the drill therein with its shaft rigidly held and prevented from rotation. In such case if the axes of both cone and drill were in one line, the point of the drill would be ground to a single cone, a copy of the grinder and its lips would have neither clearance nor cutting action; but if the two axes were parallel and separated to the extent of half the central space between the flutes, and the axis of the drill was slightly inclined vertically to that of the cone grinder, fig. 30, the one lip

would be ground to a conical superficies giving the requisite cutting and clearance angles; and the second lip would become a precise copy, if the drill were turned half way round upon its axis and readvanced within the cone to the same depth as for grinding the first. Such a hollow cone, however, would have insufficient grinding surface to be of practical use, and is replaced by the flat periphery or the flat annular face of an emery wheel or grindstone, and the positions that would be given to the axis of the drill with respect to the side of the cone grinder are copied by different methods of holding and moving the drill by hand, in appliances to aid the hand, or in machines, upon the peripheries or annular faces of the emery wheel or grindstone used.

Twist drills to about one inch in diameter, are ground with no great difficulty and with a fair approach to accuracy by hand on the ordinary grindstone; individuals differ in the methods they prefer, but most employ the flat edge of the grindstone revolving away from them. Some place the rest for the tool about an inch distant from the stone and hold the drill firmly pressed down upon it, the shaft grasped in the left hand, knuckles uppermost, with the butt end in the right; the end of the drill projecting beyond the rest with one of the cutting edges, *a*, horizontal, and the shaft inclined at the horizontal angle which presents this edge parallel with the axis of the grindstone. The drill is first advanced into contact with the stone to grind the cutting edge, *a*, and is then steadily tilted up on the rest as its fulcrum, to continue and rather increase the extent of this grinding uninterruptedly into the backing off of the whole surface of the lip to the point, *b*. It is then turned half way round in the hands upon its own axis and the second lip is ground in the same manner, after which the two edges are examined by the eye as to their equality in length and back slope, and are corrected by further grinding as may prove necessary. The rest may be roughened with a file to prevent slipping, with which object, and also to more exactly feel the action of the stone upon them, the smaller drills are held differently. The forefinger of the left hand, with the thumb upon it, is stretched out along the rest, and the drill held in the right is presented to the stone at the appropriate horizontal angle

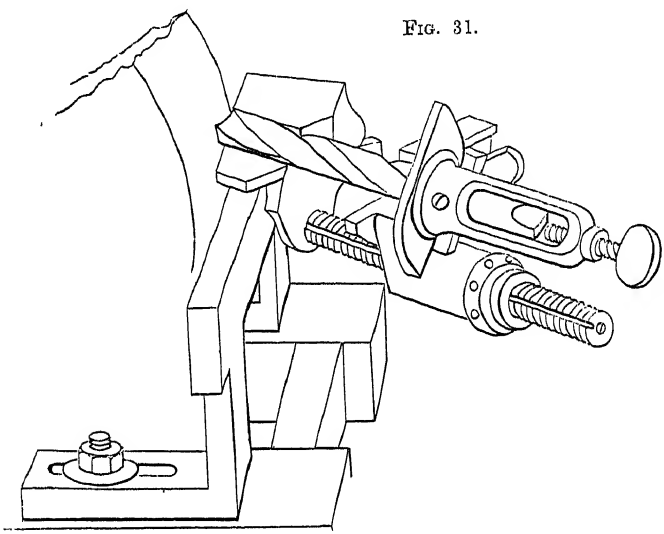
as before, pressed down on the side of the finger and against the end of the thumb, and these latter slightly turn around the edge of the rest, with the drill, as that is tilted up.

In an alternative method of grinding, easily acquired and generally preferred as more under control, the rest is placed closer to the stone and considerably above its axis, by which latter adjustment the curvature of the periphery of the stone is used to give the angle of the cones of the lips, after the same manner as it is used in fig. 9, to give different cutting angles to other tools presented horizontally to it. The shaft of the drill grasped in the fingers of the right hand with the butt end in the palm, is presented with its axis horizontal and at right angles to that of the stone with one of the cutting edges *a*, vertical and below, and rests throughout the grinding in the corner formed by the finger and end of the thumb of the left hand laid on the rest in the manner lately described. The drill is first advanced straight forward to grind the cutting edge *a*, and then without diminishing its contact with the stone, it is twisted round on its axis through about a quarter of a rotation from left to right, whilst at the same time the butt end is slightly depressed to continue the grinding in the backing off from *a* to *b*; here the curved edge of the grindstone and the movements given to the drill approach the theory of fig. 30, in the conical surface they produce on the lip of the drill. The second lip is ground in the same manner, and one or both are corrected after examination until they prove alike. This method is far more certain for the smaller drills than that first described, but small drills are more difficult to grind correctly by either, because they cannot be grasped and have to be held in the fingers, and also because it is less easy to feel the extent and equality of the action of the grindstone upon the much smaller surfaces under operation.

Apparatus is clamped or used on the ordinary tool-rest to aid the guidance of the drill when ground by hand. In one form patented by Mr. Edmeston, 1886, fig. 31, there are two flat horizontal rests in the same plane, the rearmost adjustable towards that next the grindstone and fixing upon a screwed rod to accommodate the length of the shaft of the drill; and the major portion of the surface of each is rebated down diagonally to a lower level, so that the drill when lying in the corners of

the double fence thus formed is presented to the periphery with the one conical lip to be ground parallel with the axis of the grindstone. The drill throughout the grinding is retained in the corner of the rebate of the front rest by the left hand, and whilst in contact with the upright face of the rebate of the back rest, it is first advanced to the stone to grind the one cutting edge *a*, with that edge horizontal; it is then partially rolled over by its butt end from right to left along the flat surface of the back rest to continue the grinding from the

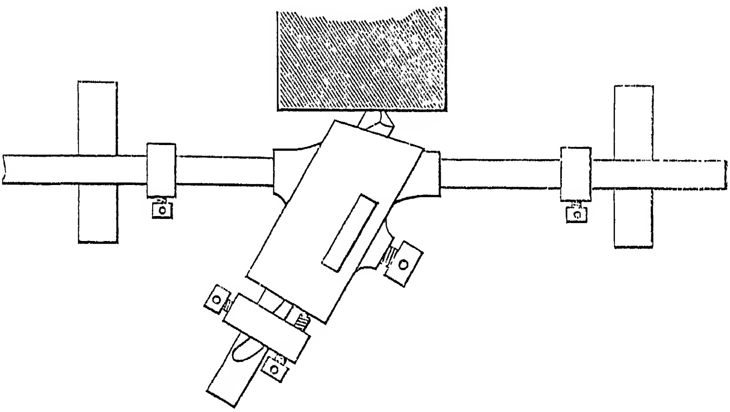
Fig. 31.



cutting edge *a*, around the surface of the one lip to its termination at *b*. The extent of the advance of the drill and that of its rolling traverse, which latter and the consequent alteration of the horizontal angle of its shaft give the backing off of the lip, are both determined by means of a flanged carrier clamped on its butt end. This serves as a handle, and by the contact of its face with the edge of the back rest, limits the advance, and also by the curved ends of the flange which, as the carrier is turned, travel against an adjustable stop fixed on the back rest, and limit the extent of the traverse. The two ends of the flange are precisely alike, so that a repetition of these operations, after the drill has been lifted, turned half way round on its axis and replaced, grinds the second lip in precise agreement

with the first, and a tail screw in the carrier regulates the projection of the drill beyond the flange ; the apparatus may be clamped anywhere along the edge of the grindstone, to use that portion which may be in the best condition. Another apparatus for use with an ordinary grindstone or emery-wheel, fig. 32, patented by Mr. Hoffmann, 1890, copies the movements given to the drill in the method first described for hand grinding. It consists of a block mounted diagonally to the axis of two round rods fixed into its sides, and pierced in the direction of its length with a < shaped mortise, which

Fig. 32.



carries the drill fixed therein by a clamping piece and set-screw at the side, and presents the one lip at the appropriate angle to the edge of the stone. The rods rest in angular notches in the surfaces of supports on either side of the frame of the grindstone, adjustable to or from the axis of the stone to accommodate the differing projections of the cutting ends of large or small drills, or, if the supports be permanently fixed they have several parallel notches for the same purpose. In use, the left hand is pressed on the block, and the lip of the drill is moved through an arc of a circle on the revolving stone by the right hand raising and lowering the butt end of its shaft, the apparatus turning on the rods in the notches of the supports as its center. The block and rods are attached, so that the line bisecting the angular mortise, or the axis of the drill, is a

little above the axis of the rods, which effects the backing off of the lip; and a collar with a set screw clamped on the shaft of the drill in contact with the rear end of the block after the one lip has been ground, ensures a precisely similar advance through the block when the drill has been turned half way round for grinding the second. Besides its partial rotation the apparatus slides to and fro in the notches to traverse the drill across the face of the grindstone, but should the latter be

Fig. 33.

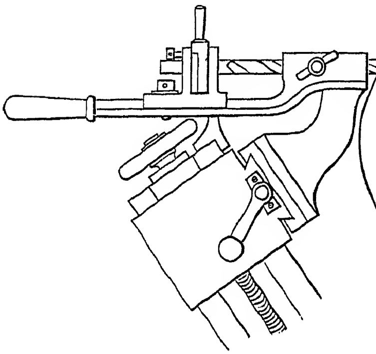
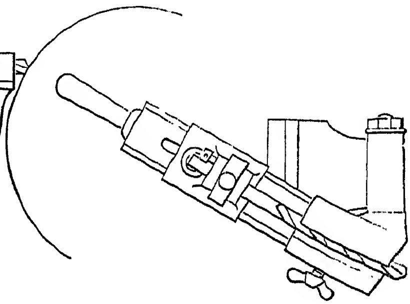


Fig. 34.



unevenly worn, collars are fixed on the rods against or near the supports, either to prevent all traverse or to limit that to a portion of the stone in good order; and lifting the holder from its supports allows examination of the progress of the grinding.

The machines most commonly used put the drill through similar movements to those given by the apparatus last described, their general construction is indicated by figs. 33, 34. A main slide provided with a traversing screw with a wheel handle is bolted by its lower end to the frame of the grindstone or emery-wheel so as to stand at a vertical angle, and it can usually be moved on its principal bolt as on a pivot and be refixed, to vary its inclination as the stone wears to a smaller diameter. The upper surface of the moving portion of the main slide has a second and horizontal slide cast with it in the solid, which is at right angles to the main slide and parallel with the axis of the grinding wheel, and the top plate moved by the traversing screw of this second slide is

furnished with a bracket-shaped arm that projects towards the wheel, and terminates close to it in a long horizontal pivot parallel with its axis.

The holder for the drill consists of a flat bar curved upwards at its front end, above which it terminates in two upright sides a few inches long; the inner vertical face of the one side is planed out as a < groove, and that of the other is provided with a clamping piece advanced by a thumb-screw to hold the drill in the groove. The butt end of the drill is received in the taper-hole of a circular collar carried by a movable head, having a small power of vertical and horizontal adjustment to place the aperture in the collar in the axial line of the shaft of the drill in the < groove, to accommodate drills of different diameters and the head itself is moved along and fixed by a binding screw in a slot in the bar for those of different lengths. The collar is also provided with stops and a handle to turn the drill one half over to grind the second lip exactly opposite the first. The drill holder is secured and moves on the pivot of the bracket by a socket forged with it in the solid, planted on the side close to the end and at an angle to the direction of its length, fig. 34; by this arrangement the shaft of the drill receives the horizontal inclination to present its lip parallel with the axis of the stone, and the line bisecting the < groove stands a little below the plane of the axis of the socket to give the backing off of the lip. The grinding is commenced at the cutting edge with the holder horizontal, and resting on a support fixed to the end of the main slide as in fig. 33, and continued by moving the holder up and down by the handle at its rear end to grind the backing off, during which the holder is also traversed to and fro across the face of the stone by the cross slide; the amount ground away is regulated for the first lip, and exactly repeated for the second by the movement of the main or inclined slide, and the point of the drill is plentifully supplied with water throughout.

In a machine indicated in the plan diagram fig. 35, patented by Messrs. Bancroft and Thorne of Philadelphia, U.S.A., 1883, the drill is presented with its axis *a*, horizontal, at the appropriate angle to the face of an annular emery-wheel, and is partially rotated upon a second axis *b*, in a plane a little below, and at a horizontal angle to the axis of the drill, to effect the

backing off of the lip. The drill is gripped close to its cutting end, and centrally between the two jaws of a scroll chuck, and has its butt end supported on a center in a head which may be moved along and clamped upon a rod *a*, that projects from the back of the chuck parallel with its axis and that of the drill. The chuck itself is carried by and rotates with a mandrel *b*, made in the solid with its back, the axis of the mandrel placed at a lower level and at an angle to that of the chuck; the rear end of the mandrel is contained and rotates in a long conical fitting in a fixed head, and the front annular face of this fitting is notched out to act as stops against the stem of a counterpoise handle by which the mandrel is moved, to limit the partial rotation of the chuck and drill to the extent of the

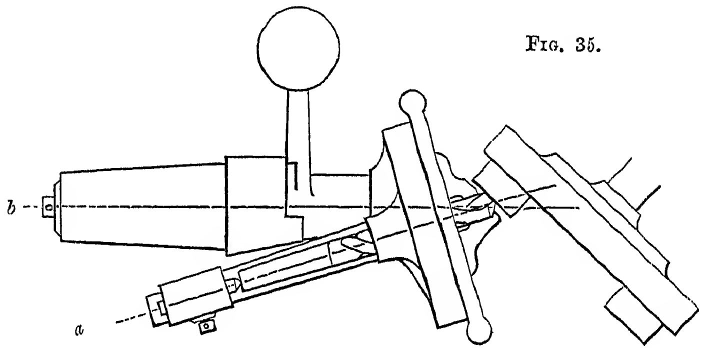


FIG. 35.

conical superficies of the one lip being ground; the movement given to the drill being analogous to that which would result with the supposititous grinder, fig. 30.

The drill when first placed in the chuck is rotated by the fingers until the sides of the spiral flutes *a*, *a*, fig. 28, arrive in contact with projections on the one side of each jaw, and is then fixed, and when it is released and turned half way round to grind the second lip these sides are again placed in contact with the stops before it is refixed, which ensures that each lip of the drill has occupied precisely the same position with respect to the diametrical line of the chuck; besides this, the lip of the drill out of contact with the grinding wheel abuts against a hook or finger at the end of one of the jaws, to limit the extent the drill can project through the chuck, that each lip may receive the same amount of abrasion. The head-

stock has a regulated advance towards the drill to determine the extent of the grinding, and it also receives continuous lateral reciprocation to equalize the wear on the annular face of the wheel; the base of the head supporting the mandrel *b*, is secured to the frame below in a circular fitting, and may be slightly turned either way and then fixed, so as to vary the horizontal angle at which the shaft of the drill is presented to the emery-wheel to grind the lips to obtuse or more acute cones for boring different materials.

In a machine patented by Mr. Griffiths, 1887, used on the periphery or on the annular face of the emery-wheel, the shaft

FIG. 36.

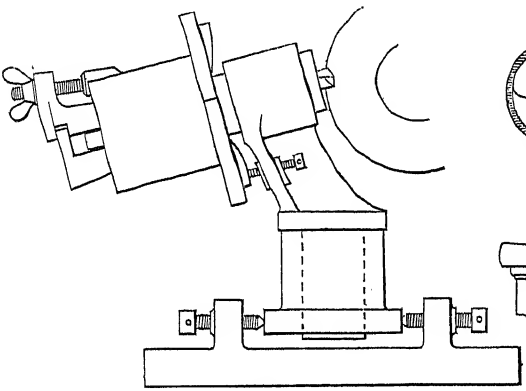


FIG. 37.

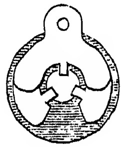
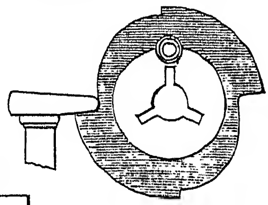


FIG. 38.



of the drill held at a vertical inclination is advanced to the wheel, partially rotated on its axis, and oscillated on the lip being ground, simultaneously and in a very simple manner, under the guidance of cams ingeniously combined upon the drill holder. The moving parts are as follows: an oblong plate, shown endwise in fig. 36, with an upright socket at about the middle of its length, which is about twice that of its width, is held at one end between center screws at the base of the machine, and has a vertical screw at the other end, not visible in the illustration, by which it may be raised or lowered on these centers, so that the vertical socket may be inclined either way to present the drill to different parts of the width of, and to equalize the wear on, the annular face of the emery-wheel. The oblong plate is also adjusted laterally between its center screws to place the axis of the socket in the plane of

the face of the emery-wheel, and when these two adjustments have been effected it is securely clamped by the same three screws. A round pillar turns freely within the socket, and carries a bracket-arm, which terminates above in an internal cylindrical fitting to receive the drill holder, which latter is formed of two cylinders one larger than the other, with a flange-formed cam-plate between them, all in one solid, of which the smaller cylinder fits and turns in the hollow fitting in the arm. The parallel bore throughout the length of the holder is planed with three equi-distant radial tapering grooves which carry corresponding wedges, of which the wider ends terminate in portions of flanges, one of which overlaps and bears against the surfaces of the other two, figs. 37, 38; a fly-nut upon a screw fixed in the end of the holder, presses upon this one flange, and advances all three wedges simultaneously, until their inner straight edges grip and bring the drill central within the holder. The edge-cam of the flange has duplicate opposite portions, fig. 38, that bear against the rounded edge of an adjustable arm of similar shape to the tee rest of a lathe, not shown in fig. 36, and cause the gradual variation in the horizontal angle of the shaft of the drill, and limit and arrest its rotation. The face of the flange, fig. 36, is also provided with duplicate cams, which bear against a screw in the arm, and regulate the advance of the drill to the wheel, and this screw may be raised in the arm, and then fixed so as to use any portion of the face cam of more or less curvature, and both face and edge cams influence the backing off of the lip. In use, the drill first lightly held by the wedges is pushed forward into contact with the wheel, and then fixed by a turn of the thumb-screw, after which the holder is twisted round to and fro by the hand, pressed forward against the screw in the arm, and sideways against the tee rest, the shaft of the drill as it partially turns also oscillating on its lip on the pivot of the arm in the socket below. The amount ground away is increased by partly withdrawing the screw in the arm. To grind the second lip the holder is withdrawn just clear of the tee rest, turned half-way round, re-advanced and used as before until the face cam arrives in contact with the screw, which has remained as finally adjusted when grinding the first, the two lips are then alike; the horizontal angle of the shaft of the drill is varied to

grind the lips to more obtuse angles, by diminishing the distance between the adjustable tee rest and the axis of the pillar or pivot upon which the arm swings.

The machine represented by figs. 39 and 40, patented by Messrs. Higgins and Morgan of Worcester, Mass., U.S.A. 1890, presents the drill with its shaft at a vertical inclination to the annular face of an emery-wheel. The drill is oscillated horizontally upon the center of the curve to which its lip is ground, whilst the axis of its shaft stands a little to one side of the plane of that of the vertically-inclined pivot upon which it is moved to effect the backing off; besides which, the V grooves in which the drill lies are planted on the holder so

Fig. 39.

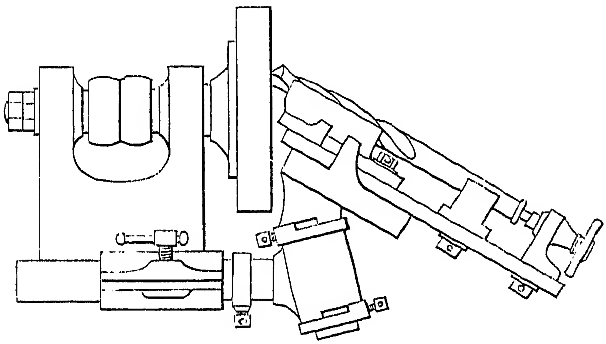
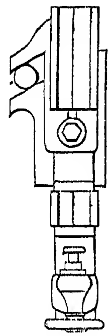


Fig. 40.



that the plane which bisects their angle is not vertical, but inclines a little to the right, hence the larger the diameter of the drill placed therein the further its axis is removed from that of the pivot upon which it oscillates.

A round shaft parallel with the mandrel of the emery-wheel slides within a split tubular fitting at the side of the base of the headstock, and is fixed at any position within it by a compressing screw; beyond, it carries a loose collar with a set screw, which, by contact with the face of the tubular fitting determines the traverse of the shaft in the one direction, and the shaft terminates in a transverse socket at a vertical inclination, bored with a plain hole to receive the shaft pivot of the drill holder. A portion of the lower annular surface of this socket is cut away, and the upper end is turned down as a rebate to receive a similarly notched collar which is fixed upon

it by a set screw, and these by their contact with a notched portion at the upper and a corresponding collar placed on the lower end of the shaft pivot, when adjusted and fixed by their set screws, limit the extent of the horizontal oscillations of the drill holder. The shaft pivot is in one solid, with a flat inclined table, which has a projecting jaw at one side for a purpose which will be explained, and the drill holder is composed of a long bar fixed on this table; a flat piece with a short V-grooved head for the fore end of the drill, slides lengthwise on the bar, and when adjusted is fixed by a binding screw passing through the bar into the table,—the side of which piece carries a corresponding jaw to that previously mentioned, a second angular grooved head to support the after-part of the shaft of the drill, and a popit head with a screw and flange that is placed in contact with its butt end, which two last pieces slide, and are fixed by set screws in a slot in the bar for drills of different lengths.

The holders of most of the machines in which the drill is oscillated vertically or horizontally upon the axis of the cone to which its lip is ground, are provided with some form of stop adjusted by a graduated scale to project the end of the drill the amount required beyond the axis upon which it moves; twist drills are usually marked with their diameters, and the stop at the front end of the drill holder is fixed accordingly. The jaws, mentioned in fig. 39, perform this function automatically; the rear-jaw is fixed to the table on the vertically-inclined pivot, and the front-jaw is attached to the side of the base plate of the angularly grooved head for the front end of the drill, and therefore slides with this plate when that is moved along the bar of the holder. In addition, about one-half of the open end of the angular groove next the emery-wheel is covered by a thin piece of steel, a portion of which enters one of the flutes of the drill, and serves to retain the one cutting edge *a*, fig. 28, in the line bisecting the angular groove, and also by means of a second small projection which bears against the cone of the lip not being ground, somewhere near the point *b*, fig. 28, places a limit to the advance of the point of the drill beyond the end of the holder, all of which stop is well away from the face of the emery-wheel. The apparatus is first placed a small distance from the wheel by the traverse of the shaft at the side of the

headstock, and the shaft clamped. The drill is then callipered between the jaws, which causes the plate and the front V head to travel towards the grinding wheel, the distance necessary to bring the center of the conical curvature to which its lips are to be ground over the axis of oscillation, that of the inclined socket, and the base plate of the front head is then fixed to the bar by its binding screw. The drill is next laid in the grooves of the heads in contact with that portion of the stop which gives the position for the cutting edge of the lip to be ground, and supported by the flange of the popit head, so that the other lip is not far from contact with the projection on the stop which determines the extent of its subsequent advance; the whole apparatus is then moved back until the end of the drill touches the grinding wheel, and the horizontal shaft is reclamped. The grinding is effected by oscillating the holder by hand, with the one hand laid on the drill, and the other from time to time advancing the screw of the popit head until the grinding away of the one lip causes the other to bed against the projection on the stop; the drill is then turned over to grind the other lip. By partly rotating and then fixing the horizontal shaft, the holder may be canted, and the drill ground on any portion of the breadth of the annular face of the wheel to equalize wear; this partial rotation of the horizontal shaft is also employed to traverse a diamond tool, temporarily held in the front head, across the face of the emery-wheel when the truth of the latter requires renewal; during this operation the shaft is relieved of the pressure of the tubular fitting, and the collar is fixed upon it, to secure an equal depth of cut, as the diamond is traversed to and fro across the face of the annular emery-wheel.

SECT. III.—SHARPENING CUTTING TOOLS ON THE OILSTONE.

The completion of the edges of tools after grinding is effected either upon the Turkey or Arkansas oilstone, or on one of the family of hone slates described on page 63. These stones differ exceedingly in quality, some being so hard as scarcely to take any hold of the tool, whilst others are altogether as soft. The latter are perhaps best for broad tools, as they cut rapidly, and are then less exposed to being irregularly

worn than when used for narrow tools, for which last the harder stones are preferable.

On the whole, the preference is given to the two oilstones named for ordinary tools, and to the yellow German hone for razors and delicate instruments. These oilstones being crystalline, are cut into square pieces with the slicer fed with diamond powder; but the hone slates may be split through their natural fissures into rough parallel blocks, and before use they are ground flat by rubbing them on a wide stone, or iron plate fed with hard sand or emery. The stones are afterwards mounted in wooden stocks, as explained under OILSTONE, article 3.

In sharpening, as in the majority of mechanical operations, the work becomes a copy of the tool, and a flat oilstone, now the tool, will produce the most correct edge with the least expenditure of time. The oilstone should be kept flat principally by an even distribution of the wear; the stone or iron plate must, however, be occasionally resorted to for restoring a level surface. The oilstone should be moistened with good clean oil not disposed to dry; otherwise it becomes thick like glue or varnish, and entirely prevents the action of the stone upon the tool. Soap and water have been recommended for razor hones, but its rapid evaporation is unfavourable to its use.

The angles at which the tools are sharpened for different materials have been already treated of in the preceding volume. It is there mentioned that the ultimate angles of the ordinary tools for wood vary from about 25 to 45 degrees, according to the hardness of the wood and the manner in which the tool is applied. The smallest angle, or about 25 degrees, is used for the spokeshave iron. Paring chisels and gouges are generally sharpened at about 30 degrees, and plane irons at about 35 degrees. Turning chisels and gouges vary from about 30 to 45 degrees. The screw tools and moulding tools for hardwood and ivory are made at from 50 to 60 degrees, and as already stated, their angles are preserved by sharpening these particular tools upon their faces only. Tools for iron and steel have angles of from 60 to 70 degrees; and those for brass and gun-metal from 80 to 90 degrees.

In all cases in which the sharpening of the tools is completed upon the oilstone, the principal part of the material is

removed upon the grindstone, at an angle a little less than that forming the ultimate edge of the tool, the greatest differences being made in the tools for soft wood which only require a moderate degree of strength in their edges, such as the plane irons, paring chisels and gouges, which are generally ground about 10 degrees more acutely than they are sharpened. In the tools for metal, which require considerable strength in their edges, the difference is not more than about 2 degrees. It is therefore necessary in all cases that the shaft of the tool to be sharpened should be held at such an angle to the surface of the oilstone, as to place the edge of the tool at the required angle. Thus, if a tool with one bevil only, such as a plane iron, is to be sharpened at an angle of 40 degrees, the shaft of the tool is held at an angle of 40 to the face of the oilstone; but if a tool with two bevels, such as a turning chisel, is to be sharpened at an angle of 40, its shaft must be held at half that angle, or 20 degrees, so as to place the second bevil at the angle of 40. It consequently results from the tools being placed at two different angles on the grindstone and oilstone respectively, that the chamfer of the tool presents two bevils, the one produced by the grindstone, the other by the oilstone, and these, in the case of the tools for soft wood, are quite distinct, but in the tools for metal gradually merge into each other.

It has been already said that some practice is required to enable the tools to be held steadily upon the grindstone at the proper angle, the same remarks apply to setting tools upon the oilstone; but in the latter case the difficulty is increased by the necessity for rubbing the tools backwards and forwards upon the quiescent stone. With a little care and practice, however, the hands acquire the habit of traversing the tool at the same angle in parallel lines, and this is quite essential, as should a rocking motion be given to the tool in the direction of the bevil during the stroke, the chamfers instead of being flat would become rounded, and the ultimate edge of the tool would be thereby thickened and unsuited for its purpose.

Rectilinear tools that are sharpened upon the one bevil only, require to be laid flat on the face to remove the wire edge; this is done as the last process of setting; the tool should be rubbed upon the face no more than is absolutely necessary,

and not in the least degree tilted up, which would produce a second bevil and greatly increase the angle of the edge, at the same time destroying the accuracy of the face given in the manufacture of the tool.

The method of sharpening a plane iron has been described somewhat in detail at page 496, Vol II., the peculiar mode of holding the plane iron is there stated as follows:—"The iron is first grasped in the right hand, with the forefinger only above and near the side of the iron, and with the thumb below; the left hand is then applied with the left thumb lapping over the right, and the whole of the fingers of that hand on the surface of the iron; the edge should be kept nearly square across the oilstone, as when one corner precedes the other, the foremost angle is the more worn." This method of holding the tool gives great steadiness and command of position, and it should be adopted with all rectilinear tools that will admit of its application, as the back of the tool is then firmly supported upon the three fingers of the right hand assisted by the two thumbs placed beneath, while the pressure is given almost exclusively by the fingers on the top of the blade.

Narrow chisels that are too small to be grasped in both hands, are held in the right hand much the same as a plane iron, and the pressure is principally given by the first two fingers of the left applied near the edge of the tool and over the forefinger of the right hand.

Chisels that are required for paring across the end grain of moderately soft wood, are considered to hang better to the work when they have a very slight keen burr or wire edge, thrown up on the face of the tool; to produce this they are sharpened quite smoothly as usual, but for the last finish the bevil is passed once or twice over the stone as in sharpening, which raises a minute wire edge sufficient for the purpose.

Cabinet-makers' gouges that are sharpened externally, and are required to have the edge square across the end of the tool, are held in the right hand the same as small chisels, and traversed straight along the oilstone with the shaft at right angles to the side of the stone; the first two fingers of the left hand are applied within the concavity of the gouge, and serve

as a fulcrum upon which the tool is twisted about one-fourth of a turn with each stroke backwards and forwards upon the oilstone, so as to subject all parts of the chamfer equally to the action of the stone; this is continued until the edge has been uniformly sharpened. The flat oilstone cannot be applied to remove the wire edge from the concave side of the tool, and this is effected with a slip of oilstone having a convex edge, the gouge is held in the left hand whilst the oilstone slip is rubbed up and down the inside of the gouge with the right hand, care being taken to keep the slip flat on the face of the tool to avoid making a second chamfer; at the last finish the side of the slip is generally swept once or twice around the outside of the edge.

Gouges that are sharpened from the inside must be set entirely with the oilstone slip, but the gouge is in this case generally rested against the bench, and the process is more tedious.

It is at all times rather difficult to keep the curved edge of the gouge level or square across the end. When the edge has become irregular from repeated sharpening, it is restored by placing the gouge perpendicular upon the oilstone and reducing the end to a level surface; after which the edge is sharpened as above described. The difficulty of sharpening to a level edge across the end of the tool is often considerable with the smallest gouges, such as those used by the wood carver, and this is generally due to irregularities in the inner curvatures or channels of these small tools, which arise from the difficulty of keeping the tiny grinding wheels by which they are ground out in shape and working order. Should this irregularity in curvature be pronounced, a level edge that is equally keen throughout becomes an impossibility: for in such tools if the sharpening be so manipulated as to bring every part of the inner and outer curvatures to a sharp edge, then this edge will be a wavy or indented line; and if it be attempted to correct this uneven to a straight line by rubbing the edge with the tool held perpendicularly on the oilstone, then the straight line so obtained is sharp at some points, and thick and blunt at others, from the reduction of the high places. Tools having this fault may sometimes have their channels ground out afresh, but they are usually abandoned in favour of others without it as the less expensive procedure.

Moulding plane irons are held in the left hand face upwards, that the operator may the more exactly see the part to which the oilstone slip is applied; the straight portions of the edge are sharpened upon the ordinary oilstone, and to remove the wire edge the iron is laid flat on the oilstone in the same manner as a chisel.

The turning chisel for soft wood is sharpened in the same manner as the paring chisel, the only differences arising from the double chamfer and the oblique edge; the extreme point of the turning chisel requires to be made quite keen, that it may be used for turning flat surfaces. The chisel is conveniently sharpened with its shaft held in the right hand with the left wrapped around it, in the manner described two paragraphs later for flat tools, but with the shaft of the tool presented at a horizontal angle to the side of the stone that the oblique cutting edge may lie nearly square across the latter; the hands are traversed parallel with the length of the stone, the main pressure being given as the edge of the chisel travels forward or from right to left upon the stone. The one bevil completed, some merely turn the tool over in the hands, others reverse the horizontal angle of the shaft and the positions of the hands to sharpen the other; the tool in the latter case is then held in the left hand with the right wrapped around it, the main pressure being then given as the tool travels from left to right.

The turning gouge, when sharpened upon the flat oilstone, is held in the same manner as the cabinet-maker's gouge, but to sharpen its elliptical edge the tool is traversed in a more concave sweep, much like the path of the parabola, upon the face of the oilstone, whilst the gouge is twisted in the hand exactly as described for grinding that of the cabinet-maker. Sometimes both the outside and inside of the turning gouge are set with the oilstone slip; in this case the gouge is held in the left hand, and rested against the popit head, or any convenient part of the lathe, whilst the flat surface of the oilstone slip is rubbed lengthways all around the external chamfer of the tool, and then the round edge of the slip is rubbed within the concave flute.

The wire edge left by the grindstone upon the gouge must be entirely removed before the tool is fit for use, it is expedited

by drawing the chamfer of the tool through a notch cut by itself in a piece of wood as hard as beech, a few touches of the oilstone slip will then render the edge perfectly keen and fit for use.

Flat tools for wood, ivory and the metals when sharpened upon the oilstone are usually held in the right hand, the forefinger straight out along the face but also bearing slightly on the side of the blade, the thumb on the opposite side and the other fingers beneath the blade, the handle passing the palm of the hand, and the left hand, knuckles uppermost, is wrapped round the whole nearly or quite covering the right forefinger. The tool is traversed straight along the stone which is placed with one end towards the operator, and the above-named positions of the hands are a considerable assistance to maintain the tool at one uniform inclination throughout its sharpening. Flat tools of moderate size are conveniently sharpened held in a different manner; the shaft of the tool is grasped in the right hand, all the fingers wrapped around it with the thumb stretched out upwards pointing along the handle, the thumb, the face of the tool, and the end of the stone all towards the operator. So held with the wrist a little bent to incline the shaft at the appropriate angle to give the edge its cutting facet, the flat tool is steadily traversed to and fro along the stone, its true position upon which is readily felt by the manner in which the edge *bites* or hangs to the stone as the tool is traversed towards the operator, the strokes by which the sharpening is principally effected.

Round tools, perhaps the most difficult of all tools to sharpen because it is necessary to arrive at a regular curvature as seen on the face, and an equal cutting bevil all around such curvature, are most conveniently sharpened held in a different manner, and with the long side of the stone towards the operator. The shaft of the tool is held like a pen with the forefinger stretched out along its face, the handle free and above the hand, with the left hand wrapped around the right, the fingers all above and the thumb below the right thumb. Thus held the round edge is traversed in a flat curve from six to eight inches long from end to end of the stone, the wrists twisted backwards and forwards to cause the entire round edge

to meet the stone, with the upper arms kept in contact with the body for steadiness. Small round tools from about a quarter of an inch wide downwards, and the small round slide-rest tools, drills and cutters used in ornamental turning, in their socket handles, are held and sharpened after the same manner, but with only the two first fingers of the left hand placed on the forefinger and thumb of the right to give the pressure. The round drills for ornamental turning are also sometimes held by their necks between the finger and thumb alone, the wrist twisted as before during their traverse.

Right and left side tools, and the sides of flat tools, have their side cutting edges traversed at right angles to the length of the stone, with their shafts horizontal. They are held in the right hand after the manner of the flat tools, but with the clenched left hand placed above the right forefinger and thumb to give the pressure. Their end cutting edges are sharpened like flat tools.

Tools for turning hardwood, ivory, and those for finishing the metals are sharpened upon the oilstone much the same as the corresponding tools for soft wood, the principal difference being that they are held upon the stone at a greater angle, according to the material upon which they are to be employed; the appropriate angles and forms for the various materials have been fully explained in the second volume of this work. Tools for steel cut the most keenly and smoothly when left from a fine grindstone. Tools for iron cut rather more smoothly when finished on the oilstone, but the edge is not so enduring and, therefore, with tools for iron the oilstone is only occasionally resorted to for giving a smooth edge for the last finish of the work. Tools for brass and gun-metal when left from the grindstone, cut too rankly, and are said by workmen to *drag;* they are therefore always sharpened upon the oilstone, and the finishing tools for brass and gun-metal are frequently burnished, as mentioned at page 522 of the second volume; in this case the burnisher is placed at right angles to the face of the tool, and passed once, or at most twice, across the edge with moderate pressure.

Finishing tools for soft wood are sometimes burnished with the back of the turning gouge applied at an angle, to throw up a wire edge which is used with a scraping action. The

broads, figs. 372 and 373, page 515, Vol. II., are thus employed for flat surfaces. Right side tools, fig. 382, ground at an angle of about 30 degrees and burnished, serve for the interiors of boxes, and ordinary paring chisels are used in like manner for finishing cylindrical and convex works. The method of sharpening the joiner's scraper with the burnisher is explained at page 484, Vol. II.

SECT. IV.—SETTING RAZORS.

Perhaps of all cutting instruments, the razor possesses the most general and personal interest in respect to the conditions required for its perfect action, and it is therefore proposed to notice at moderate length the principal circumstances on which the perfection of its edge depends.

The razor notwithstanding the peculiarity of its outline, conforms strictly to the ordinary wedge form section of most cutting tools, but as it requires the most delicate edge that can be produced, it is so formed as to facilitate to the utmost the process of sharpening. For instance in the plane iron, chisel, penknife, lancet and most other instruments, the angles of the one or both the sides of the wedge or cutting edge are determined by the particular inclination at which the tool is held upon the stone, but if the hand wavers, the setting or facet instead of becoming a plain flat surface becomes rounded and ill defined.

In the razor on the other hand the proportion between the width of the blade and the thickness of the back, is almost always such that when the blade is laid perfectly flat on the hone, or so that the edge and back both touch, the suitable angle is obtained, and this varies from about 17 to 20 degrees; the exact measure of the angle is very little studied, although in reference to the principle of cutting tools some little variation ought to be made, in choosing the thickest edge for the strongest beard. It does sometimes happen that the razor is not laid quite flat on the hone, but that it is slightly tilted, this occurs when a wide razor that has been ground on a large stone is required to be sharpened for a stiff beard; but it so rarely occurs that the razor is placed otherwise than flat on the hone, that the exception may be overlooked.

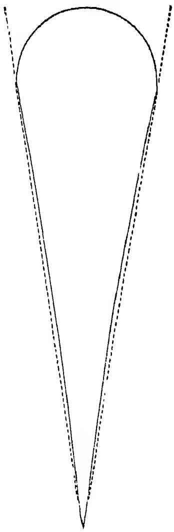
The enlarged sections of razors in figs. 41 to 46, which for distinctness are drawn three times their full size, and for comparison, of the same angle or 18 degrees throughout, exhibit various modes adopted to avoid the necessity for sharpening the entire side of the imaginary wedge, represented by the dotted lines, by hollowing the sides in different ways. It is apparent that it would be much more tedious and difficult to wear down the imaginary flat sides represented by the dotted lines, than the small portions of the same which are supposed to remain; and indeed the entire dotted line if sharpened, would most probably become rounded instead of flat. The concavity therefore facilitates the placing of the razor on the hone, it thins the edge leaving but little for the stone to abrade, and it prevents the finished appearance given to the sides of the razor being deteriorated by the sharpening.

Figs. 41 and 42, represent the section of that description of razor blade which is by far in the most common use; as before observed the widths of the blade and the thicknesses of their backs are such as to give in each an ultimate edge of 18 degrees when the blade is sharpened on the hone, but fig. 42, is ground transversely on a wheel of four inches diameter, and fig. 41, on one of twelve inches, the general extremes of curvature. It is clear that the first named possesses an edge that is thinner and more flexible, and that presents a narrower edge or plane to be abraded by the hone; which latter in consequence will cut with greater precision and delicacy than if it had to abrade the entire surface. The curvature in most general use for best razors is intermediate, or from 5 to 6 inches, but stones of from 12 to 15 inches diameter are from motives of economy resorted to for common razor blades.

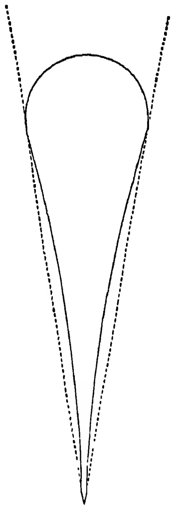
In some few cases the edge of the razor is ground lengthways on the stone, so as to become nicked in in the manner represented in fig. 43, and in this way any degree of thinness may be given and extended throughout any desired width. This mode of grinding the razor is however more difficult, and the feebleness of the edge may be thereby easily carried to excess; and from the vibration to which they are liable when applied to a strong board, they are called by the Sheffield cutlers *rattler* razors. Sometimes the two methods of grinding are combined, as shown in fig. 44, in this case the razor is

first ground transversely as for fig. 42, and it is subsequently ground lengthways so as to be nicked in for about half its

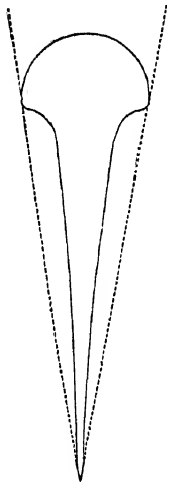
Figs. 41.



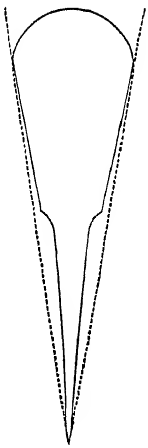
42.



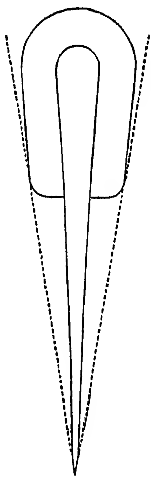
43.



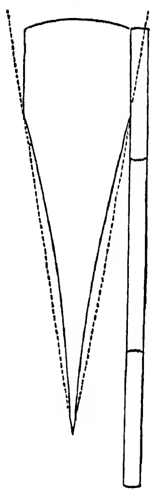
Figs. 44.



45.



46.



width; these razors are known by Sheffield workmen as half rattlers. For the sake of variety the longitudinal grinding is sometimes only extended about one quarter of an inch from the edge.

For another kind of fig. 42, known as hollow-ground razors, the stone employed is of still smaller diameter to largely increase the curvatures of the sides, and the grinding is continued until the edge becomes so flexible that it very readily yields and bends when pressed on the finger-nail. The objects sought are to attain the keenest possible edge, which shall also be so thin that the razor may be kept in order by the oilstone alone without the necessity for any subsequent grinding; but as a large part of this excessive grinding has to be carried out after the blade has been hardened, the extremely thin edges of these razors not uncommonly partially soften or lose their temper under the process. A better form, fig. 45, attains the desired results in a satisfactory manner, and is free from the above-named risk to the blade; in this a very thin and acute blade, ground both across and longitudinally, is fixed in a separate steel back and tang, somewhat after the manner of a dovetail saw, and this back and the edge of the blade are simultaneously whetted on the hone.

Fig. 46 represents another of the modes in which razors are occasionally constructed, in this a loose frame or guard of brass is added to the blade. The idea in this case is to prevent the liability to accident incurred by nervous or infirm persons from the tremor of their hands. The frame is intended to act as a muzzle or guard to prevent the edge penetrating to any serious depth, and the instrument is known as a guard razor.

The keenness of the edge of the razor is commonly tried by making a faint incision in the thick skin covering the inner edge of the palm of the left hand, but the cutler also tries the razor upon the thumb or finger nail. The razor is either placed in a line with the finger and obliquely across the end of the nail, or a still more sensitive test is to place the blade at right angles to the finger and allow it to rest upon the back of the nail, that of the third finger being by some considered the most sensitive. In this manner a very minute notch in the edge is quite perceptible, and the keenness may also be appreciated by the degree in which the razor hangs to the nail, as the keen blade will make the deeper incision and

appear to offer a more dragging yet smooth resistance, whereas the blunt razor will slide over with less penetration and drag.

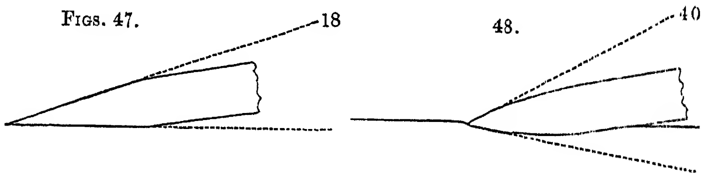
A more scientific method was proposed by the late Mr. Kingsbury in his pamphlet on the razor, namely the examination of the entire edge with a magnifier, which process when applied in a sufficiently powerful degree will doubtless exhibit the causes why the razor fails in its purpose, which are sometimes threefold, namely, first the razor may be notched, secondly it may have a loose pliant film or wiry edge, or thirdly, instead of a keen acute edge it may be blunt and obtuse, which is generally due to the excessive use of the razor strop; upon each of these considerations some few observations will be offered. First, notches are liable to occur in a razor from the blade having been overheated either in the forging or hardening, a fault which is irretrievable, as it renders the steel permanently brittle and altogether incapable of receiving a fine acute edge, as the particles of the metal break away at the extreme edge on the hone. The brittleness may occur in a somewhat less degree when the razor without having been overheated is simply left too hard, so as to require to be let down or tempered a little lower than at first. Secondly, the wire edge generally occurs from the hone being too much used, as when the two faces of the wedge are rubbed away beyond *that point at which they first meet*, the slender film of steel commences to form, because the extreme edge is then so thin that it bends away from the hone instead of being rubbed off. The wire edge is more liable to occur when the one side of the blade is more whetted than the other, and if it be obstinate in its resistance to removal, it frequently indicates further that the blade is too soft, for if the razor blade be made too hard, the metal will be brittle instead of flexible, and the thin extremity break off instead of forming the filmy edge.

The temper ought to be such for the blade to be indisposed to become either permanently notched or wiry from the action of the hone. But in the application of the various grinding and polishing wheels, especially in the latter, there is always some risk, as the temptation to expedite the work causes too much vigour to be occasionally used thus giving to the blade so much heat as to reduce its temper, an error the unscrupulous may easily gloss over, by finally touching the

work more lightly, and thereby removing the colour, the index whereby the temper of the instrument is commonly estimated. But the experienced cutler is generally able to distinguish by the feel of the cut, or of the action of his own particular hone, between such blades as either exceed or fall short of the appropriate temper.

Thirdly, in a new or a recently ground razor, the thick obtuse edge shows that the blade has not been sufficiently rubbed on the hone, and in a used razor, it more commonly indicates that partly by its continued use, and partly by its being intermediately stropped to renovate the edge, it has been too much rounded; so that instead of the two narrow facets constituting the edge being plane surfaces and meeting at from 17 to 20 degrees as left from the hone, they are seen to have become considerably rounded, so as probably to meet at more than double the original angle, a condition explained

Figs. 47. 48.



by the diagrams figs. 47 and 48, in which for perspicuity the extreme edges are shown about twenty times their true size. This fault or the rounded edge is also readily detected with the magnifier, and is almost sure to occur from the use of a *soft* strop, as the leather immediately against the edge from being indented, rises as an abrupt angle and destroys the keenness of the blade. If however the razor at any of its stages of manufacture or setting have been treated without uniformity, it may possess at different parts of its edge all these errors, but this is less to be expected than that the one error should prevail.

If none of the above three faulty conditions are discernible by the careful use of a lens of one half to one third of an inch focus, (or of a linear power of twenty or thirty,) such razor will in general be found to act with satisfaction, but the keenest razor when delicately examined with a lens of one fifth to one tenth of an inch focus, (or a linear power of fifty to

one hundred,) or still better with a microscope of not less than equivalent power, will present a faintly undulating and irregular edge, which resembles rather a ripple mark, than the angular teeth of the edge of the saw, to which it is usually compared. Indeed the edge of a razor of ordinary quality bears the microscopic examination much better than might be expected; but as no surface polished by art is free from scratches, it must happen that every such scratch when continued to the edge formed by two planes meeting at so small an angle, deprives the otherwise continuous edge of a small portion of its material, and thence constitutes a notch, but the notches are the smaller the finer the abrading surface used in producing the edge. When however the errors are so minute as to require to be thus magnified some fifty or one hundred times to render them visible, they are too minute to be detected by the skin, the nail, or by the employment of the instrument on the beard. The good and bad condition of the razor thus explained, the practice of setting the instrument will be the more easily understood, and it is proposed first to describe the sharpening of a new razor and then that of one which has been rendered dull by use.

Various kinds of whetstones are more or less used in sharpening razors, commonly in pieces measuring from eight to ten inches long by one and a half to two inches broad, and great importance is deservedly attached to their being perfectly flat on the face, with which view they are occasionally rubbed on a large gritstone with water, but in use they are always supplied with oil and kept remarkably clean.

The Charnley Forest stone is generally preferred for the first stage or for striking off the wiry edge of the blade. The Turkey or Arkansas oilstone is sometimes used for the same purpose. The Green hone or Welsh hone, which is harder than the Charnley Forest, and generally in smaller pieces, is occasionally used for razors, and is by some preferred to Charnley Forest for finishing pen and pocket knives, and especially for setting surgeons' instruments.

The yellow German hone, particularly the slabs from the lower strata known as old rock, is greatly preferred to all the

above for the principal work in setting razors, as it cuts more slowly, smoothly and softly than any of them. The Iron stone or slabs of the hematite iron ore are occasionally used for giving the final edge; it consists principally of oxide of iron and chemically resembles crocus, but that it is in a compact instead of a disintegrated form. The iron stone is however so very hard that it appears to act more as a burnisher than a hone and renders the edge almost too smooth, so that when at all used, the razor is in general only passed once or at most twice on each side along the iron stone.

Taking the razor from the last stage of its manufacture as described page 40, it is to be observed that as the glazers and polishers revolve *away from* and not towards the edge, they always leave a thin filmy edge, which, as the first step towards setting, is *struck off* on a Charnley Forest stone. The blade is grasped in the right hand by its tang and near to the cutting part, and is placed square across the one end of the stone but tilted at about ten to twenty degrees, and is then swept forward along the stone, edge foremost in a circular arc, so as to act on the entire length; each side in general receives only one stroke, and this produces a comparatively obtuse edge measuring from forty to sixty degrees. Should this fail to remove the wiry edge, the blade is placed perpendicularly upon and drawn with a little pressure across a strip of horn, (generally a spoiled razor handle,) which is fixed down to the bench, the friction of the horn against the edge generally suffices to entirely remove the wiry film, otherwise the blade is struck once more on each side along the stone. Should the film of steel be left on the stone, it is removed before another blade is applied. One object in the striking off is to avoid the necessity for so far wearing down the back of the razor as to give it the appearance of an old one that has been repeatedly set, and it is also especially required in wide blades ground on large stones, as the wiry film is then very difficult to remove otherwise.

The next and principal part of the setting is accomplished almost invariably on the German hone. The razor is held as before, but it is now placed quite flat down, or so as to touch on the back and edge. Some prefer a long sweeping stroke backwards and forwards, others prefer small circular or

elliptical strokes, and others a short zig zag movement, but all gradually work from heel to point, or draw the razor forward so as *to act on all parts alike*, and most persons lift the razor endways towards the conclusion, allowing its point still to rest on the hone, with the view of sharpening the circular end of the blade. The choice of these methods seems to be principally a question of individual habit, and to be nearly immaterial provided the entire edge be acted on alike, and that at very short intervals the razor be turned over so as to whet it upon its opposite sides alternately, but it is general to conclude the process by sweeping the razor edge foremost, once on each side steadily along the hone, as if in shaving off a thin slice of the hone, this lessens the disposition to the wire edge.

The line of policy is just to continue this secondary process until the new facets constituting the wedge of seventeen to twenty degrees, exactly meet at the extremity of the more obtuse angle given by the striking off, and this if mathematically done, would prevent the formation of the wiry film, which is one of the most troublesome obstacles in the process. Should the film nevertheless arise, it is to be removed by passing the blade occasionally across the slip of horn, and continuing the whetting for shorter periods on each side; some persons indeed suffer the film if very minute to be abraded on the razor strop, but this latter unless very cautiously used is a very mischievous instrument. It is also to be understood that the hone is not given up until at any rate the notches are no longer perceptible when the blade is drawn across the thumb or finger nail, which detects them more faithfully than the slip of horn, and that when viewed edgeways, the edge is merely discovered as the meeting of the two sides of the blade and not from possessing itself any visible thickness or width. As before observed, the blade is by some persons passed once on each side along the iron-stone, but this practice is by no means common, and may, according to the questionable doctrine advanced by some cutlers, spoil the blade by rendering it *too smooth, or too free from the saw-like teeth*, but this it would appear can hardly be the case, unless it also increase the angle of the edge, so as to render it less acute and keen.

When the edge of the razor admits of being drawn smoothly across the horn, and moreover is not distinguishable by the eye, the hone may be considered to have fulfilled its purpose, and the razor is slightly stropped, but in this case, as the edge of the blade becomes somewhat embedded in the leather, it would cut if moved forwards as in setting, and therefore the razor is always stropped backwards and usually from heel to point.

Disregarding the high sounding names and praises bestowed on various razor strops, it may be said that within moderate limits, they are the better the harder their surfaces and the less they are supplied with abrasive matter. As when they possess the opposite qualities of softness and superabundance of dressing, or when they are used in excess, they rapidly round the edge of the razor, and change its edge from the well-defined angle of seventeen or twenty degrees produced by the stone, to twice that angle or more and entirely unfit it for use.

For the razor strop a fine smooth surface of calf skin, with the grained or hair side outwards, is perhaps the best, it should be pasted or glued down flat on a slip of wood, and for the dressing almost any extremely fine powder may be used, such as impalpably fine emery, crocus, natural and artificial specular iron ore, black lead, or the charcoal of wheat straw; each of these two latter act as abrasives in consequence of containing a minute portion of silex. Combinations of these and other fine powders, mixed with a little grease and wax, have been with more or less of mystery applied to the razor strop. The choice appears nearly immaterial, provided the powders are exceedingly fine and they are but sparingly used. One side of the strop is generally charged with composition, and on the other the leather is left in its natural state, and the finishing stroke is generally given on the plain side. Some strops are of square section with three sides charged with powders of increasing degrees of fineness and one plain, for finishing; with the intention that the coarsest side may partially replace the hone, to be followed by the consecutive use of the others to complete the stropping.

It is of great importance that all razor strops be kept scrupulously clean, and with which view they are provided with

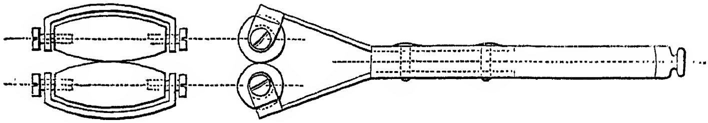
sheaths, which should be marked so as to prevent the composition being accidentally carried over to the other side or sides of the instrument. The strop should be always employed in the most sparing manner, so as rather to wipe than rub the razor; many, indeed, never strop the razor *after use*, but simply wipe it dry on clean wash leather, a silk handkerchief, or a soft towel, and only employ the strop *before* using the razor. A good mode has been suggested to preserve the edges of razors and surgical instruments from rusting when laid by, namely, the drawing them lightly through a tallow candle: this leaves a minute quantity of grease on the edge, which defends it from the air, and becomes deposited on the strop before the blade is used.

When a razor, from continued use and stropping, has become dull, it mostly arises from the edge having been rounded and thickened as explained by the diagram, figs. 47 and 48; in this case the setting, if attempted by the amateur, may with advantage be only so far pursued as barely to remove the rounded part. On close inspection it will be seen that the part of the facet towards the back is first touched by the hone, the effect of which is shown by the less polished surface it leaves; and if the setting be only continued until the bright rounded part is all but removed when examined with a magnifier, no wire edge will be formed, and the blade will be again brought within the province of the razor strop. The razor, after having been repeatedly set, becomes so wide in the bevil or facet, as to require to be re-ground, to thin it away to the first state, as the blade should always be so thin as to be sensibly pliant at the extreme edge when pressed flat on the thumb nail and slightly tilted; but the regrinding should be done with a proper regard to the relative width of the back of the blade, and the preservation of its proper temper.

An instrument somewhat analogous to the wheel knife sharpeners used for table knives, was invented by the late Sir John Robison for setting the edges of razors, pen-knives, and surgical instruments, and is shewn halfsize in figs. 49, 50; it consists of two barrel-shaped agates mounted on pivots, and free to revolve in an elastic frame of sheet brass. The surfaces of the agates are supplied with finely pulverized corundrum, emery, or oilstone powder, and the edge of the blade to

be sharpened is passed with slight pressure between the two agates, which from their shape can only be in contact at the central point; hence both sides of the edge are acted upon at the same time, and if too much pressure is applied, the elastic

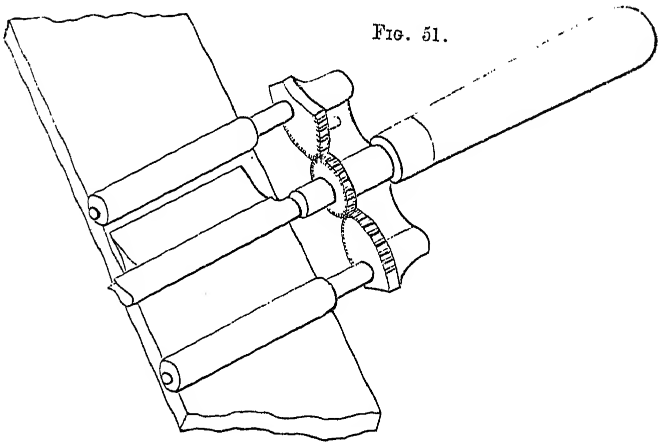
FIGS. 49. 50



frame allows the agates to separate and avoid injury to the edge of the blade.

Fig. 51 shews an ingenious patent apparatus used for stropping the blades of Kampfe's Safety Razor; which blades are of the section of fig. 42, but otherwise short parallel pieces one and a half inches long, square at the ends, with their corners slightly rounded. In this razor the blade is held in

FIG. 51.



an oblong metal frame close on the top of a comb, the teeth of which project just beyond its edge; the comb traversing the skin slightly in advance of the edge of the blade in nowise impedes the action of the latter, but entirely prevents the possibility of accidentally cutting the face. This perfectly successful razor is an American reconstruction and improvement upon an old and well known English patent razor, which

latter has a blade of the ordinary shape provided with a comb acting in the same manner, and is still used by many individuals and in hospitals.

The apparatus fig. 51 consists of a crosspiece carrying three spindles, all in metal, their axes in one plane, and a handle. The central spindle, which is free to revolve in the handle, is formed at its upper end as a thin sheath to receive the blade to be sharpened, and its lower end is provided with a small toothed wheel. The two external spindles are covered with vulcanite cylinders of equal diameter and carry sectors of toothed wheels, gearing with and twice the diameter of that on the central spindle; these are also free to rotate, but all three spindles are prevented from making complete revolutions by means of two pins, fixed equidistantly in one of the sector wheels, which arrive in contact with the sides of the cross piece to arrest them. Both vulcanite cylinders bear on the face of the strop, and when traversed along it from right to left, as in the figure, both turn until checked by the one pin and place and retain the blade with its edge bearing on the strop in the direction shewn; the stroke along the strop completed, the apparatus is traversed in the other direction, when both turn again by their surface contact until checked by the other pin, partially rotating the central spindle along with them and thus turning the blade over upon its *back*, and retaining it in the reverse position to that shown during the return journey; and so on alternately stropping each side with every pair of strokes. The second vulcanite cylinder is required to maintain the whole level with the surface of the strop; and the machine is found to perform its functions very satisfactorily.

CHAPTER III.

GRINDING AND SHARPENING CUTTING TOOLS TO PRECISE FORMS AND ANGLES.

SECT. I.—SHARPENING HAND CUTTING TOOLS WITH ARTIFICIAL GRINDERS.

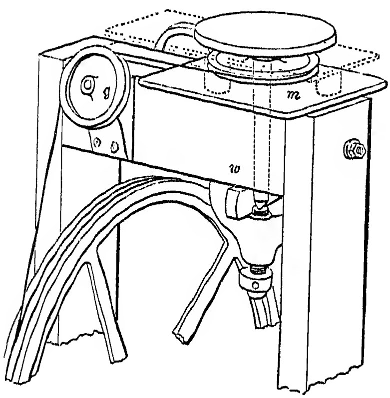
FIG. 52 represents the upper part of a horizontal grinding machine used for more carefully grinding and setting the edges of cutting tools by means of revolving laps of metal fed with the various abrasive powders. The lower part of this apparatus exactly resembles that of the vertical grinding machine, fig. 5, but to place the sides of the laps in a horizontal position, the apparatus is furnished with a vertical spindle or mandrel, upon which the laps are screwed after the manner of chucks upon an ordinary turning lathe. The mandrel is mounted in a rectangular frame of cast iron, which fits between the bearers and is secured in its place by a wedge beneath, as shown at *w*. The upper side of this frame is made as a platform, and is fitted in the centre with a cylindrical steel collar, within which the mandrel revolves while its lower end rests upon a centre screw passing through the bottom of the iron frame: by means of which the mandrel can be elevated to the required position, nearly level with the upper metal platform, which latter is dotted in the drawing, and serves as a support for the tools. This second platform stands upon three feet, fitted with pins that enter corresponding holes in the under platform; by which arrangement the upper platform can be readily removed when the laps are exchanged. The band for driving the mandrel proceeds from the foot wheel over the two oblique guide pulleys *g*, to the pulley *m*, fixed on the vertical mandrel, and the tension of the band is adjusted by shifting the mandrel frame to the right or left upon the bearers.

The general application of the revolving laps has been already described in the Catalogue of Abrasive Processes,

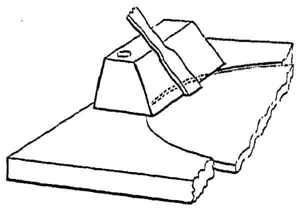
under the head WHEELS, articles 39 to 49, and it only remains to observe that, the lead lap supplied with emery of different degrees of coarseness is used for grinding the tools to the required angle; they are afterwards smoothed upon the brass lap fed with flour emery, or oilstone powder, and the final polish is given with the iron lap supplied with crocus; the two latter powders may be applied either by putting on the oil and powder separately in small quantities, and mixing them with a brush, or the materials may be mixed in a cup previously to their application.

Various guides are employed for determining the exact

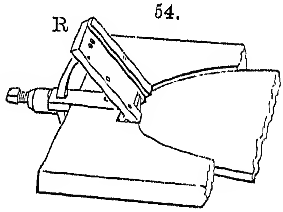
FIGS. 52.



53.



54.



angle at which the tools should be applied to the revolving laps, and also to remove the difficulty of grinding the bevils of the tools perfectly flat; the most simple consists of a block of wood shown in fig. 53, and made to the same angle at which it is required to grind the tool, the block is screwed upon the upper platform of the horizontal grinding machine, and the back of the tool being held steady upon the bevelled side of the wooden guide block, the chamfer of the tool is readily ground to that particular angle, this method however requires a separate guide for every different angle.

An instrument called a quadrant rest is shown in fig. 54, and which removes the necessity for several guide blocks; this is made of brass, and consists of a base piece that is let

into the platform of the horizontal grinding machine, a rising plate R connected to the base piece by a joint at the edge close to the lap, and retained at any required angle by the arch piece and binding screw S, and a steel rib fitted on the upper surface of the rising plate against which the tool is held whilst being ground. For determining the exact angle at which the instrument is fixed, the arch piece is either graduated into degrees, or small holes are drilled at every five degrees, into which the point of the binding screw enters. The tool to be ground is held with its back upon the upper surface, with its side in contact with the steel rib, but the quadrant rest like the wooden guide blocks, is unprovided with the means of determining the horizontal angle of the tool, which is therefore left to the dexterity of the operator; they are both objectionable also on account of always presenting the tool to the same part of the lap, which is thereby liable to irregular wear. These objections are entirely removed in the instrument next described.

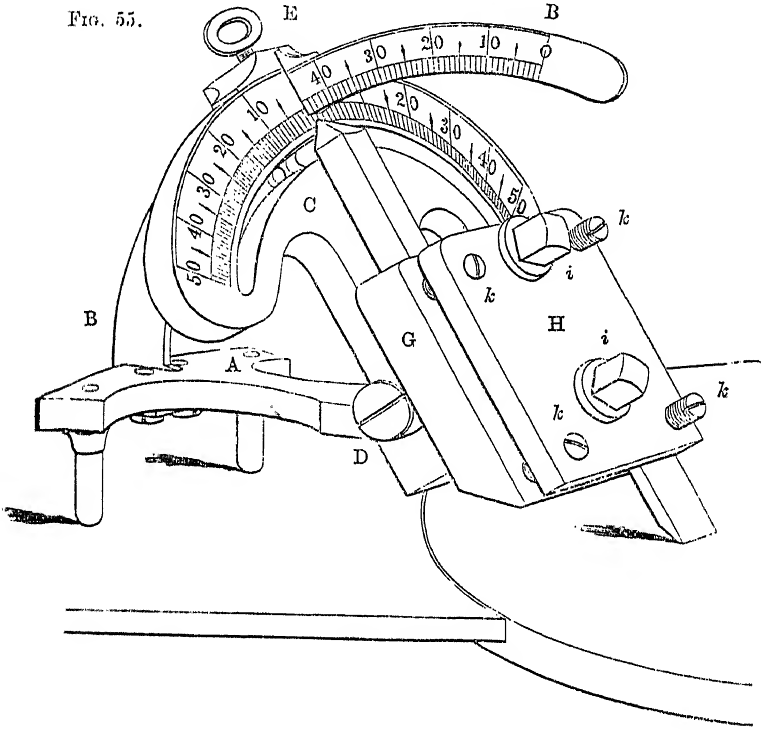
The goniostat for grinding and setting ordinary turning tools having rectilinear edges shown in figs. 55 to 58, is a modification of that used for sharpening the ends of tools employed in eccentric and ornamental turning, for which works the tools are so arranged as to their stems as to admit of their being all held in the same socket; but this would not answer for the ordinary hand turning tools which have stems of different sizes according to their respective purposes.

The principle employed in the construction of fig. 55, is to fix the tool to be ground to a triangular frame having two points of bearing, and to allow the point of the tool to be ground to form the third bearing; if therefore the two feet of the instrument are supported on a plane parallel with the grinding lap, whilst the third leg of the triangle, or the tool to be ground, rests upon the revolving lap, the latter will grind away the tool until its surface agrees throughout with the plane of the lap and in consequence the end of the tool will ultimately be made perfectly flat. As however tools for turning are required to possess a variety of forms, some square, others bevelled or pointed, others to cut at the side, and that their edges should be more or less acute according to the material upon which they are employed, it is essential to give

the socket which holds the tool two adjustments, the one vertical, the other horizontal, and both furnished with divisions and clamping screws for determining every required position to be given to the tools.

The general arrangement of this goniostat will be sufficiently

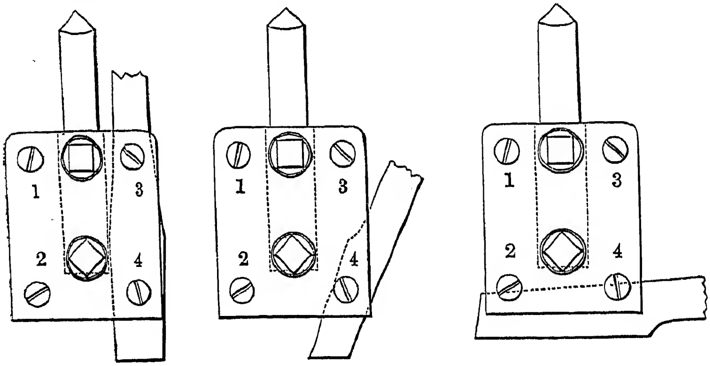
FIG. 55.



obvious from an inspection of fig. 55, in which A, represents the base of the instrument on which is fixed the vertical arch-piece B, an adjustable plane C, is connected with the base by a joint at D, on which it moves, and may be fixed by the binding screw E, at any angle from 0, at the top of the arc B to 60 degrees, lower than which it is never required to be placed; the upper part of the plane C, has a circular mortise, and is graduated through an arc of 50 degrees on each side of the central line. The piece G, which serves as the bed for the tool to be ground, is bevelled away behind its front edge that

it may not come in contact with the lap, and a pointed rectangular bar proceeds from the back of this piece to the semicircle of graduations on the plane C, to which the bed piece G, is united by means of a pivot a little in advance of D, consequently the bed piece is capable of being moved to the right or left, and it can be fixed at any angle on the graduated arc, by means of a capstan headed screw passing from beneath the plate C, through the circular mortise into the upper end of the bar of G. On the upper surface of the piece G is a steel plate H, fastened by two square headed screws, *i*, *i*, and this plate has a spring underneath which raises it to admit the tool which is to be ground. The four screws marked *k* are for regulating the height of the steel plate, so as to leave the same opening between the plates on the side unoccupied, as on that where the tool is fixed, the application of these screws

Figs. 56. 57. 58.



is shown in figs. 56 to 58, which represent the manner in which different tools are fixed in the instrument.

A flat tool is held as in fig. 56, the small screws 3 and 4 are each withdrawn a little above the under surface of the steel plate H, and the screws 1 and 2 are projected forwards through it for its support; the screw 1 being as much in advance of the under surface of the plate H, as the thickness of the tool at 3, and the projection of the screw 2, being equal to the thickness of the tool at 4, now therefore the steel plate will be supported equally on every side, and it will bear flat on the tool and hold it firmly when clamped by the square headed

screws. Without the aid of the screws to support the plate on the opposite side to the tool, it would only bear upon the edge of the tool and would not hold it firmly, the adjustment of the small screws however admits of the tool being firmly fixed, notwithstanding that it may be of irregular thickness.

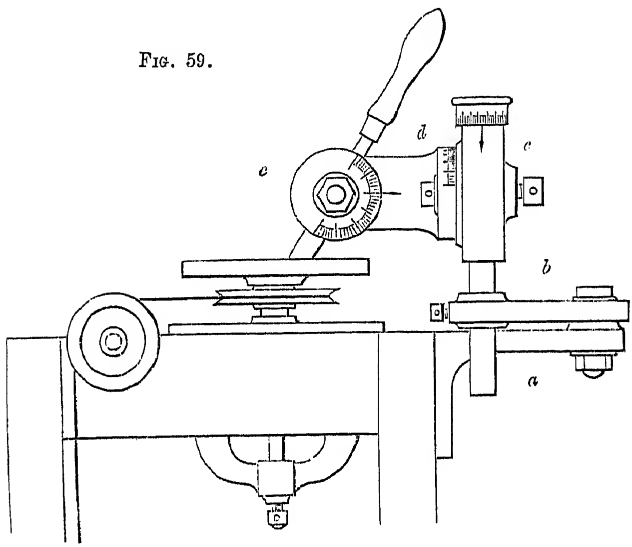
Point tools to be ground at angles not exceeding 50 degrees, may be clamped in the same manner as flat tools, and the angular position be obtained by shifting the point of G to the required graduation on the plane C, the socket is then secured by the capstan screw. When the angle of the tool exceeds 50 degrees it is clamped in the manner next described. Bevil tools are more conveniently fixed as in fig. 57, in which case the screw 4 is withdrawn, and 1, 2, and 3, are advanced to equal the thickness of the tool. Side cutting tools are held as in fig. 58, screws 2 and 4 being withdrawn, and 1 and 3 adjusted to the thickness of the tool.

The tool having been firmly clamped, the vertical and horizontal angles are adjusted until its cutting bevil bears fairly upon the lap, when also the two legs of the instrument rest upon the platform of the grinding machine. To avoid the rapid deterioration of the lap, it is desirable to distribute the wear by applying the tools to different parts of its surface in succession. For grinding the tools to definite facial and cutting angles fig. 55 is adjusted by means of its two graduated arcs, and in the same manner as the goniostat employed for the angular tools used in ornamental turning, described later.

Mr. Alexander Gray, an amateur, has contrived an adjunct to the horizontal grinding machine, fig. 52, for the purposes fulfilled by the instrument last described, and this, which he patented in 1887, also somewhat resembles the swing arm of the lapidary apparatus, fig. 361. A flat faced bracket, *a*, is bolted towards the back of one of the uprights of the frame of the machine, and supports a horizontal arm, *b*, pivoted to the extremity of its surface, the other end of which arm is pierced with a cylindrical hole and carries an iron post fixed therein by a binding screw. A flat faced block, *c*, bored throughout the greater part of its length fits on the upper end of the post and is prevented from turning upon it by the pointed end of a screw, which passes through one side into a groove cut down the upper half of the post; and the block may be adjusted

higher or lower on the post by means of a screw with a graduated head, which fits upon a cylindrical portion of the top of the block, like a cap, the end of the shaft of this screw bearing on the top of the solid post. The other face of the block has a circular fitting, *d*, graduated in degrees, and this, when it has been adjusted to give the angle required for the cutting

Fig. 59.

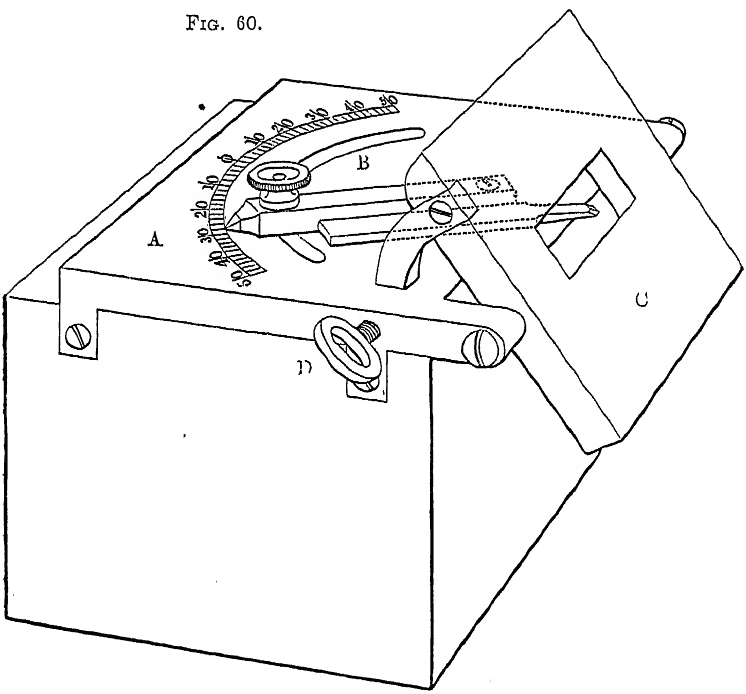


bevil of the tool, is secured by bolts which pass through circular mortises into the face of the block. A second circular fitting, *e*, at right angles to the first, at the end of a short diametrical arm, made in the solid with the latter, is set and fixed by its central bolt to the facial angles of the tool, the stem of which is gripped in a Professor Willis' tool holder, fig. 1007, Vol II., attached to its other side. Less reliable because less stable than the goniostat, the apparatus nevertheless serves fairly well and has the merit of simplicity of construction; in grinding, the shaft of the tool is clamped under the two pins of the holder, the third and screw pin of which is adjusted according to the thickness of the shaft, the two circular fittings are then fixed to give the facial and cutting angles, and the post is lowered and fixed by the binding screw in the horizontal arm, *b*, until the edge of the tool touches the face of the grinder; the tool, moved by the arm on the bracket,

is then swung to and fro on the face of the revolving lap, and is gradually lowered as the grinding progresses by withdrawing the screw in the top of the block. When the first side of a point tool is completed, the other is ground to the same length and angles, by raising the block on the post, setting the second circular fitting over to the opposite angle, and again lowering the block throughout its grinding until the graduations on the screw read as they previously did for the first.

Fig. 60, represents an instrument that is very generally employed by practical rose engine turners, for sharpening their small angular sliderest tools, which require a considerable degree of accuracy. This apparatus is provided with two

FIG. 60.



planes jointed together, upon the one of which the tool to be sharpened is placed in the required position for grinding the horizontal angle of the edge, whilst the second plane serves for determining the vertical or cutting angle of the chamfer.

The instrument consists of a horizontal brass plate A having a circular mortise and a graduated arc for denoting the angle at which the central guide bar B is placed, this bar moves upon a pivot near the front edge of the plate A, and is fixed in any angular position by the clamping screw passing through the circular mortise. The vertical plate C, is jointed near its middle to the edge of the plate A, and can be fixed at any inclination within its range by means of the arc and clamping screw D.. This plate has a central rectangular opening through which the end of the tool may project as seen in the figure, in order to allow of the action of the grinder, which is usually a flat piece of oilstone about three inches square embedded in a wooden stock; at other times a piece of hard brass supplied with fine flour emery or oilstone powder is used as the grinder, this retains a level surface for a longer period than the oilstone, which must be occasionally ground flat upon a level plate charged with emery.

The apparatus is generally attached to the frame of the lathe, but to render it portable it is sometimes fixed to a block of wood sufficiently heavy to give it stability; the tool to be ground is held nearly stationary by the left hand, laid face downwards upon the horizontal plate, with its side in contact with the guide bar, which is fixed at the angle required for the horizontal edge of the tool, the second plate is then adjusted to give the required bevil for the cutting angle. The oilstone moistened with a few drops of oil is applied with its face flat upon the vertical plate, and the tool is advanced with the fingers of the left hand, until its end touches the oilstone, which is rubbed in contact with the vertical plate in all directions by the right hand, while the end of the tool is kept gently pressing against the oilstone and this is continued until the chamfer of the tool is sufficiently sharpened. If it be a point, called a double angular tool, the position of the guide bar is then changed, and the second chamfer is operated upon in the same manner; and lastly the face of the tool is laid flat on the oilstone, and gently rubbed to remove any trifling burr that may have formed upon the edge. It is of course necessary that the tool should be held quite steadily in its position on the bed of the instrument and against the bar, notwithstanding that it is kept constantly pressed endways against the oilstone.

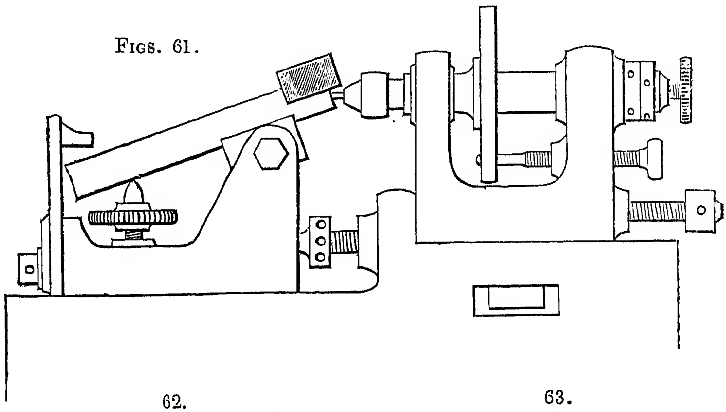
Angular tools that are used for rose engine turning on curved surfaces such as those of watch cases, are generally ground with the one angle of the edge of nearly twice the length of the other, this is done to give the tool increased strength, and allow of a rubber with a rounded end being fixed near to the point of the tool, to regulate its penetration.

Apparatus of similar character has been adopted for grinding the facets of the tools used in machines for engraving lines on copper plates and wood blocks for printing. These engraving machines are usually fairly alike in construction; the graver is mounted in a holder attached to a carriage which is traversed to and fro along the vertical face of a horizontal slide, usually by a rack on the top of the slide and a pinion in the carriage, its spindle turned by a winch handle. The slide is mounted as a bridge and stands across a turntable below, which is like a surface chuck with grooves and clamps to fix the block or plate, and the turntable is mounted on the top of a second slide at right angles to that fixed above, and is propelled along it by a screw turned by a handle, fixed in the plate of a large wheel on the end of the screw; the edge of this wheel is cut into fine ratchet teeth and is provided with adjustable detents and stops, to limit and vary the motion given to the screw to advance the table towards the traverse of the graver, according to the intervals at which it is required to cut the lines. The turntable may be partially rotated upon its axis and then temporarily fixed, and the arrangement, so far, serves for cutting all parallel lines in any direction across the work or at right or other angles to one another; besides this, with the table free to revolve, a pin near the circumference in its under surface enters a slot in a horizontal bar, which latter may be placed parallel with the screw of the second slide or at definite angles to it; the bar is usually fixed at but a small angle, and its effect is to correspondingly slightly turn the table upon its axis every time it is advanced by the screw, and the lines then cut by the uniform traverse of the graver converge as required upon objects drawn in perspective.

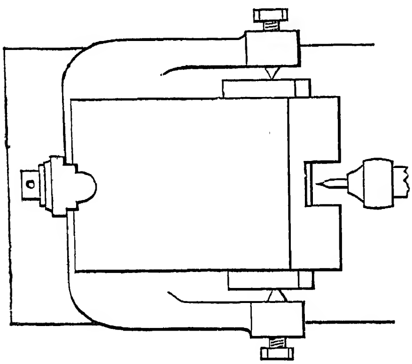
One form of toolholder, contrived by Mr. W. H. Bennett, for engraving on wood, fig. 63, consists of a vertical bracket fixed to the carriage traversed on the bridge and bent at right angles

below, where a horizontal arm is pivotted to it. The stem of the graver stands at an angle, so as to approach the position in which this tool is used by hand, and is gripped at two points on its stem under the circumference of the annular head

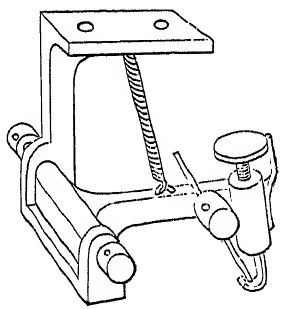
Figs. 61.



62.



63.



of a binding screw, against the flat vertical surface of one side of the end of the arm; beyond this a screw in a cylinder, raises or depresses a stop formed of a strip of steel bent round at its lower end and notched for the point of the graver to pass through it. The smooth curved end of the stop bears upon the surface of the woodblock and the depth of the line cut, that is the projection of the point of the graver through its fork, is controlled by the large head of the screw that raises the stop; the edge of this is milled or cut into fine teeth, and a vertical steel spring bears against these teeth to hold the head at any position to which it may be turned, and also to read the

graduations marked around its upper surface. In use the operator presses the stop down on the block by the fingers of one hand on the head of its screw, whilst he traverses the carriage along the bridge by the winch handle of the pinion turned by those of the other, and on relieving the pressure at the end of each line, the stop and graver are raised from the work by a weak spiral spring attached to the arm and bracket.

In this, as in most machines, the graver is removed and sharpened by hand by rubbing its facets on an oilstone, and when it is replaced the stop has to be readjusted until, by observation of trial cuts made upon some unoccupied portion of the block, it is found to cut to the same depth as before. This presents no great difficulty with most woodcuts, but it is the contrary when re-sharpening is required in the course of cutting a large number of close, uniform lines, as in an even tint for a sky, in which a variation in depth, imperceptible in cutting the block, becomes plainly visible in the subsequent impression; the re-adjustment then requires very careful manipulation, and is a matter of still more anxiety when engraving fine lines on copper.

The apparatus indicated by figs. 61, 62, patented by Mr. L. B. Benton, 1890, is employed to grind the graver to accurate facets, after the manner of fig. 60, and also to grind its point to an invariable projection from the face of its holder, and thereby avoid the necessity for a stop rubbing on the work, which is replaced by a stop which determines the descent of the holder. The latter, shown on the right of fig. 61, resembles a miniature lathe head with a hollow spindle to contain the stem of the graver, which is gripped near its cutting end by a small three-jaw chuck similar to fig. 253, Vol. IV., and is advanced to its position through the chuck by a screw bearing upon its butt end working in the end of the spindle. The cylindrical point of a second screw enters any of a series of equidistant holes in a circular plate on the spindle and holds the tool at the required positions for grinding its angular facets and also later when in use; and a third screw advances a taper block within the base of the holder head, to draw in the stem of a flat-headed bolt, by which the head is fixed in a definite position against a stop on its carriage on the bridge of the engraving machine, and in like manner against a

stop on the horizontal base of the grinding apparatus when the tool is re-ground.

The grinding instrument, shown also in plan, fig. 62, has a thick rectangular, true, steel plate attached to a transverse bar near its front end and is supported at three points, two being center screws in the ends of the bar and the third a vertical screw at its rear end upon the point of which it rests, and by raising this screw the surface of the plate may be placed horizontally or at the angle required to give those of the facets ground on the tool. The front end of the plate is notched out at its center to admit the point of the graver, and its surface above this is rebated down to about half an inch in depth to form a guide for the traverse of the grinder, usually a piece of arkansas oilstone of rectangular section, which is rubbed to and fro by hand along the rebate across the plate and the point of the tool. In use, the holder detached from the engraving machine with the tool in its place in the hollow spindle is fixed on the base of the grinding apparatus against the stop, and the head supporting the grinding plate is advanced towards it and also into contact with its stop—with all these contact surfaces first scrupulously cleansed from dust or any accidentally adhering matter—hence the distance between these two at which they are fixed on the base is always definite for the first and all subsequent sharpenings; and as the grinding effected on each facet of the tool comes to an end so soon as the block of oilstone beds on the rebate, if the tool be originally ground in the machine and that remains as at first adjusted, at all re-sharpenings it is only necessary to advance the graver a small extent through the hollow spindle of the holder before that is refixed on the base of fig. 61, and the facets are then re-ground to the same angles and the point of the tool to precisely the same projection from the holder as it was at first.

By employing the different appropriate holes in the division plate, the facets may be ground as two long bevils meeting one flat side, a form used for engraving on wood, or as three or more facets meeting in a point, a tool for engraving lines on metal; in addition, by partially rotating the guide plate on its pivots by the one hand at the rear end during the grinding effected by the block of stone traversed along the rebate by the other, the facets may be ground to a curve in the direction of

their length, to obtain a more durable point. In this latter case an adjustable stop is used to limit the upward traverse of the plate, and the extent of its downward motion, which determines the length of the point, is controlled by the height to which the vertical screw is adjusted to stand beneath it.

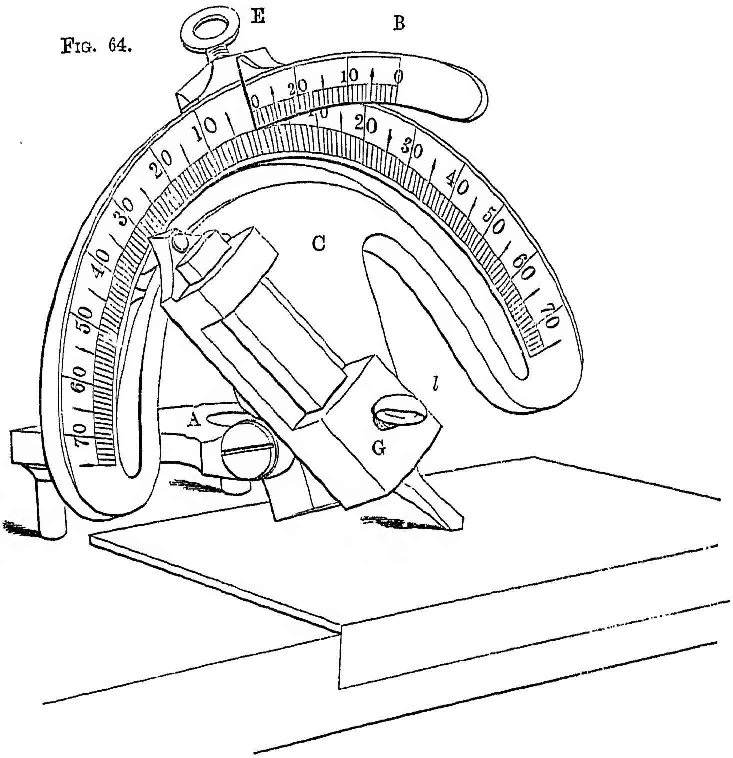
SECT. II.—SHARPENING SLIDE REST TOOLS, DRILLS AND CUTTERS USED IN ORNAMENTAL TURNING.

THE various small tools with straight and angular edges employed for eccentric and ornamental turning, are required to have very accurate, keen, and highly polished edges, in order that they may impart the same degree of excellence and finish to the cuts made upon the work, whether executed with tools fixed in the slide rest, or with revolving cutters employed in the various apparatus described in the fifth volume. These ornamental works from their intricate and delicate character scarcely admit of any polishing, and, therefore, the beauty and finish of their surfaces depend almost exclusively upon the perfection of the cutting edges of the tool, as the good or bad quality it may possess is literally copied upon the work, without the possibility of subsequent correction. Hence it is highly desirable that the edges of the tools should be formed by perfectly true planes, polished in the most careful manner, results which cannot be obtained without the assistance of suitable guides for holding the tool, and the employment of the most delicate abrasive powders.

The goniostat for grinding and setting the straight and angular edged tools, drills, and cutters used for ornamental turning, fig. 64, resembles in principle and construction the instrument employed for grinding the hand turning and other tools, lately described; but it has greater range as to the angles to which the tools may be set, and it has a suitable socket to receive the sliderest tools, the stems of which are all made to one uniform size to fit the clamping bar of the receptacle slide of the slide rest, fig. 14, Vol. V. in which they are used. Fig. 64 is nearly always employed in the reverse manner to the instrument for setting the hand turning tools, and instead of the tool being held stationary upon a revolving lap when fixed in fig. 64, it is moved and rubbed first upon a

stationary slab of oilstone and subsequently set and polished upon flat plates of metal supplied with oilstone powder and crocus respectively. This method of employing the goniostat is very convenient and quite as effective for the small tools under present consideration, from the edges of which but little material has to be removed, so that it is virtually as expedi-

Fig. 64.



tious, it has the merit also that the stationary grinding slabs are inexpensive and occupy but little space; on the other hand, those who possess the horizontal grinding machine, fig. 52, find their advantage in grinding and polishing all these small tools for ornamental turning upon its revolving laps, using fig. 64 for the purpose just in the same manner that its larger congener is employed for grinding the hand tools.

The case for containing fig. 64, has three slabs of maho-

gany, measuring about eight inches long and six and a half inches wide, fitted as drawers; into the one side of each of the slabs, and close to the edge, are inlaid respectively, a piece of oilstone, brass, and cast iron, measuring about three and a half inches by three inches. The upper surfaces of these plates are made quite flat, and they project slightly above the wood as shown in fig. 64, in which the one edge of the angular tool will be seen to rest upon the metal plate whilst the two feet of the instrument stand upon the mahogany slab, which is sufficiently large to support them whilst the tool is traversed in all directions over the metal plate.

The same letters of reference are used for corresponding parts of figs. 64 and 55, and the description of the latter instrument already given applies also to fig. 64, except that the graduated arc on C, is extended to 75 degrees on each side of the central line, and the socket G is made as a straight bar with two projecting pieces having rectangular openings to fit the shafts of the tools, which are fixed by the binding screw *l*.

To sharpen a double angular tool of 30 degrees, the instrument is adjusted as shown in fig. 64. The index point of the socket G, is placed at the division marked 30 on the arc C, which is then adjusted on the vertical arc B, to the angle required for the chamfer of the tool; in the drawing this is supposed to be 30 degrees, the cutting angle usually employed for hardwood and ivory, the tool is then placed in the socket G, and the distance which it should project therefrom is determined by placing the goniostat in the position shown in the figure, with its two legs upon the wood surface, and the edge of the tool resting upon the oilstone. The projection of the tool is then so regulated that the base piece A, may be parallel with the wood surface, and the tool is fixed by the binding screw *l*. Should the projection of the tool be such that the base of the instrument is inclined to the wood surface, the chamfer of the tool would not be ground to an angle of 30 degrees; the precise angle of the chamfer however in many cases is not absolutely important.

The instrument having been adjusted, the tool if in bad condition is first ground upon the oilstone, moistened with a few drops of oil, and the tool applied as shown in the drawing, is lightly rubbed with circular or elliptical strokes in all direc-

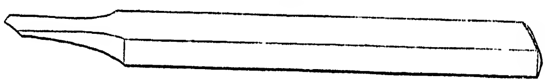
tions over the surface of the stone until a keen edge is produced upon one of its angles. The index point of the socket G is then shifted to 30 degrees on the opposite side of the circle of graduations on the piece C, and the second edge of the tool is sharpened in the same manner.

The bevils having been completely sharpened upon the oilstone, the tool is next taken to the metallic surfaces to have its edges more finely ground and polished, which is done in the following manner. Without unfixing the tool, the plate C is moved about two degrees higher upon the arc B, and the tool is then applied upon the brass surface, which is supplied with a very small quantity of oilstone powder and oil. The tool is rubbed upon the brass surface in the same manner as upon the oilstone, until the chamfer presents a narrow facet with a dull greyish polish; when both edges have been thus treated, they are very carefully wiped to remove every particle of oilstone powder, and the final polish is given by rubbing the tool upon the iron surface, which is supplied with a little crocus and oil.

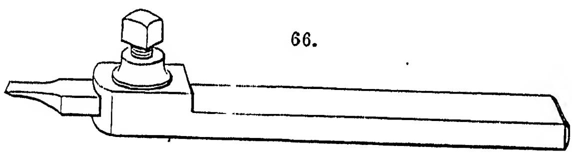
Practically the use of the oilstone slab is nearly limited to the first formation of the cutting angles, and after this it is seldom employed except to reinstate a broken edge or when from neglect the tools have worn into bad condition. The importance of the perfect formation of the rectilinear bevils of the tools and of the polish of the extreme or cutting portion of these edges, and the fact that both this form and polish are actually transferred from the tool to the work cannot be too strongly insisted upon, for brilliant successful cutting in all ornamental turning can only result from careful and sustained attention to these conditions. This is so well recognized by all practised in this branch of turning, that it soon becomes a habit to invariably sharpen and polish every tool every time it is used; and although the subject is more fully discussed in the fifth volume, it may be mentioned here, that it is also sometimes necessary to resharpen the tool during the progress of its employment to re-acquire the keenness and polish it has lost or given back upon the work. Frequent sharpening, however, is very far from being the tax it might at first sight appear, from the circumstance that a few moments suffice for this systematic sharpening of the tool

before work, and that this small expenditure of trouble at the same time entirely prevents the tool lapsing from good order so as to call for the greater labour then required to reinstate its cutting edge. In carrying out this system, a slightly different sequence suffices for sharpening all the sliderest tools, drill and cutters for ornamental turning that are originally in good form as to their cutting edges; the oilstone slab is not used, and the entire width of the bevil is first ground on the brass slab fed with flour emery and oil, after which the tool is raised about the two degrees by the vertical arc of the goniostat, already mentioned, to grind the little second facet on the extreme cutting edge on the same slab,—which second

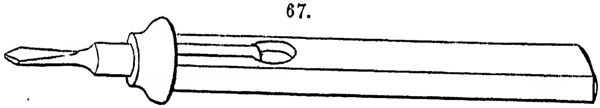
Figs. 65.

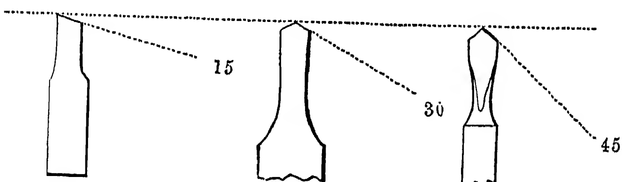


66.



67.





68. 69. 70.

bevil it should be said greatly adds to the permanence of the cutting edge,—and the tool when wiped clean from the emery and examined with a glass as to the perfection or otherwise of its edge, is finally polished, as to this little facet, on the iron slab fed with crocus powder.

The upper surface of the tool, or the flat face, has also to be kept in very good condition towards the cutting edges, this is effected by removing the tool from the instrument and laying

its face flat upon the iron surface, upon which the tool is rubbed under the point of the first finger until the slight burr thrown up in the sharpening is removed.

The revolving cutters used in the various cutting frames employed for shaping and ornamenting the surfaces of turned works, are from necessity made too short to be held in the instrument, fig. 64; these are first fixed in a holder having a rectangular mortise suited to the size of the stem of the tool, which is clamped therein by a square-headed binding screw, as shown in fig. 66, which represents a tool-holder adapted for revolving cutters of the smallest size; and similar holders, fig. 122, Vol. V. are employed for other short cutters of greater width of stems, as also others for the blades of the cutter bar for screws, fig. 523, Vol. IV. The stem of the tool-holder is made to fit the socket G, of fig. 64, in which it is secured as described for the sliderest tool, shown detached in fig. 65.

Drills, such as fig. 70, intended to be used in the drilling instrument for ornamental turning, are in like manner fixed in a holder, fig. 67; but in this case the binding screw is not required as the stem of the drill fits the cylindrical hole in the holder, and it is prevented from twisting round by a short projecting piece at the end which is filed down to the diametrical line, so as to slide into the flat-bottomed recess in the holder, and also to fit the drilling instrument in which it is to be employed, as shown in figs. 145—168, Vol. V.

The small sliderest tools which have straight *side* cutting edges, lying in the direction of their stems, such as the right and left side tools, figs. 23 and 24, Vol. V., and analogous drills and cutters for ornamental turning, have these side edges ground and polished when carried in the holder, fig. 134, Vol. V., an accurate and convenient method suggested by Sir Thomas S. Bazley, Bart. The mortise of this holder, of the size to receive the sliderest tools, is transverse to its length and, therefore, presents the side edge of the tool to the surface of the metal tablet. In sharpening a right or left side slide-rest tool, the cutting bevil is first provided for by fixing the vertical arc of the goniostat to the appropriate angle, and then the reading point of the socket is shifted one or two degrees from its zero to grind the side edge slightly out of parallelism with the stem of the tool; after which the tool is rubbed to

and fro straight along near the back edge of the grinding tablet. During this operation the surface of the wood slab in which the metal tablet is inlaid is no longer used as previously described, but the slab is placed upon some other flat surface for the two legs of the goniostat to travel upon, while the third point of support, the edge of the tool, now standing beyond one or other side of and nearly parallel with the base of the goniostat, rests on the surface of the tablet at the higher level required by the more elevated position of the latter. The side edges of the small cutters and drills are ground after the same manner, with these tools held in their appropriate holders and their holders placed in the transverse holder, fig. 134, Vol V.

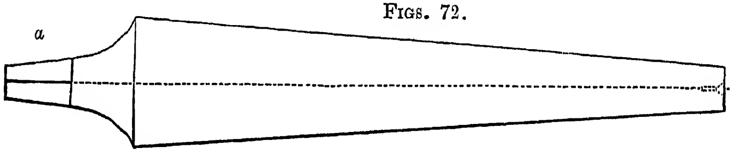
The principal cutting action of all the above-named side tools is effected by the corner or angle formed by the meeting of their side and end cutting edges, hence the straight side edge is ground very slightly out of parallelism with the stem of the tool, to give its extremity a little the more prominence and consequent avidity, and also that the entire side edge as it follows it and continues to enter the work may have just sufficient clearance not to rub; the end edges of such tools are sharpened subsequently to their side edges, the tools placed in the goniostat in the ordinary manner, as already described, but for the same reasons these end edges also are usually ground not quite square across the stems, but at a trifling inclination to it, so as to cause the two cutting edges to meet at rather less than a right angle.

To avoid uncertainty respecting the facial angles of the tools used for ornamental turning, these tools are usually stamped with figures denoting the angles at which they are ground; but it should be said that these numbers indicate the angle measured from a line at right angles to the center of the tool, or, in other words, it is the angle which is ground away that is estimated, and not the angle which the edges of the tool make to each other. Thus, in the instance of the tool, fig. 65, lately described as being ground at the angle of 30 degrees, each side of the tool is ground at an angle of 30 degrees, or the edges differ to that extent from a flat tool, and the sum of these two angles being 60 degrees it follows that the edges meet each other at an angle of 120 degrees, or the

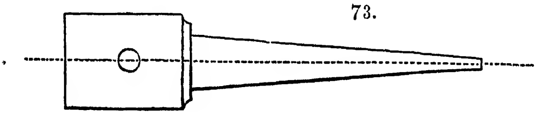
Concave tools, whose edges when seen in plan form part of a circular line, such as the bead, astragal, and quarter hollow hand turning tools, figs. 395 to 398, page 519, Vol. II., and those on page 297, Vol. IV., are most conveniently and accurately ground upon conical grinders fed with flour emery or other abrasive powders, after the manner of laps; these grinders are in the form of long cones of small diameter, so that some part of their circumference may agree with the curve of the tool, which may be then ground with great accuracy to the circular form.

Bead tools, exceeding about half an inch wide, are commonly

FIGS. 72.



73.

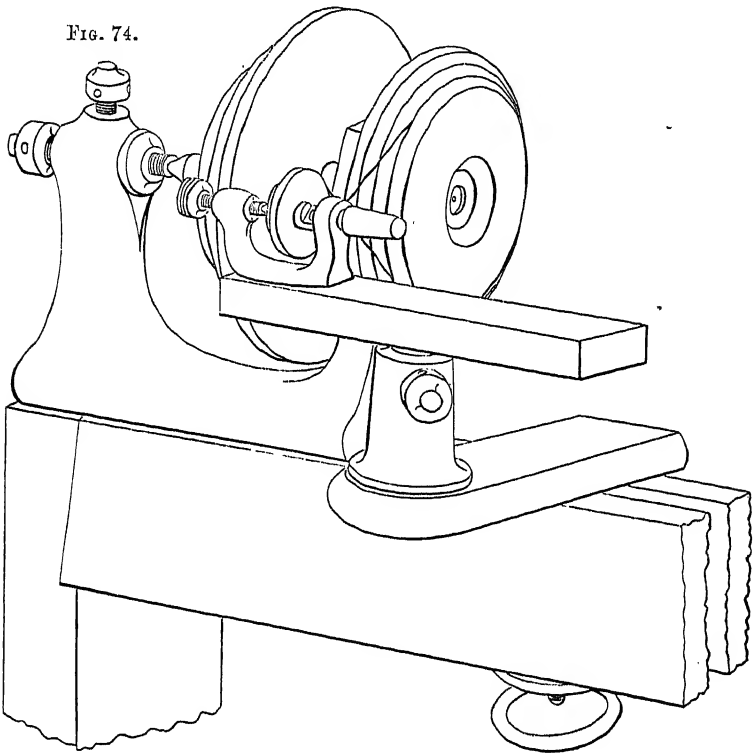


ground upon a soft iron cone, fig. 72, about seven inches long, one inch and a half diameter at the larger end, and half an inch at the smaller. The cone is generally furnished with a square tang at *a* to fit the square hole chuck of the turning lathe in which it is mounted, the smaller end of the cone being pierced in the center with a conical hole for the reception of the center point of the popit head. For tools less than about half an inch wide, shorter cones are used, fixed in a plain chuck, as shown at fig. 73, so as to be supported at the one end only, as the lesser end of the cone is too small to admit of the support of the popit head, which is also hardly required.

The cone having been turned true and to a uniform taper, and its surface slightly roughened by drawfiling, it is then charged with flour emery and oil, and the tool is applied to that part of it which fits the curve and with the face of the tool towards the small end of the cone, in order that its under side may be ground to a larger diameter, to give the proper angles of penetration and relief to the chamfer of the tool at all

parts of the curve. Large tools, which only require a moderate degree of accuracy, are finished upon a corresponding cone of lead or hard wood, fed in like manner with flour emery and oil; the emery becomes embedded in the wood and consequently gives a higher polish to the chamfer of the tool, the rectilinear corners of which are sharpened upon a flat oilstone, and lastly,

Fig. 74.

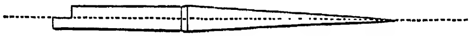


the face of the tool is rubbed on the oilstone to remove the wire edge. Quarter hollow tools are treated in exactly the same manner as bead tools and astragals.

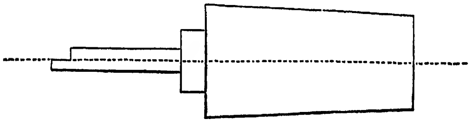
Bead tools, bead drills and revolving cutters, from about half an inch in width downwards, that are used in the various apparatus for ornamental turning, although ground in the same manner, require to have more accurate and highly polished surfaces, as already explained in reference to the angular tools; and for these delicate tools the more suitable arrangement is shown in fig. 74, the instrument for setting

bead tools and drills, which consists of a miniature lathe head mounted on a wooden table-tee, having an iron stem that fits the socket of the common lathe rest. The instrument is driven in two ways, first in the manner shown, by a grooved pulley about eight inches diameter screwed on the mandrel of the turning lathe, the band from which proceeds to the little pulley of the instrument, which method is the more generally convenient and employed. Secondly, when it is required to sharpen a tool during the progress of some piece of ornamental turning, in which case the mandrel is occupied by the work and the sliderest is fixed and occupies the position shown by the apparatus in fig. 74, and neither may be disturbed, then the pedestal carrying the grinding apparatus is clamped

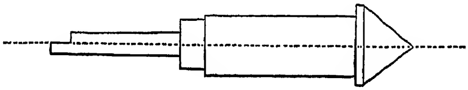
FIGS. 75.



76.



77.



on the lathe bearers somewhere beyond the sliderest and driven by a band from the overhead motion, fig. 87, Vol. V. By either mode the instrument runs at considerable velocity to compensate for the small diameter of the grinders, figs. 75—77, which are made as a series of six brass and six iron truncated cones, each a little more than one inch long and gradually diminishing in size from the largest, which measures about five-eighths of an inch diameter, to the smallest, which terminates in a point, so that the series serves for all sizes of tools below about five-eighths of an inch wide. The cylindrical stems of the grinders are fitted to a plain hole in the mandrel of the instrument; and to ensure their rotation, they are provided with a semi-cylindrical projection at the end, which slides into a corresponding notch in the mandrel of the little lathe head in the same manner as do the drills themselves in the drilling instrument, fig. 136, Vol. V. Indeed, fig. 74 is used also as a drilling lathe; and for this purpose it is conveniently

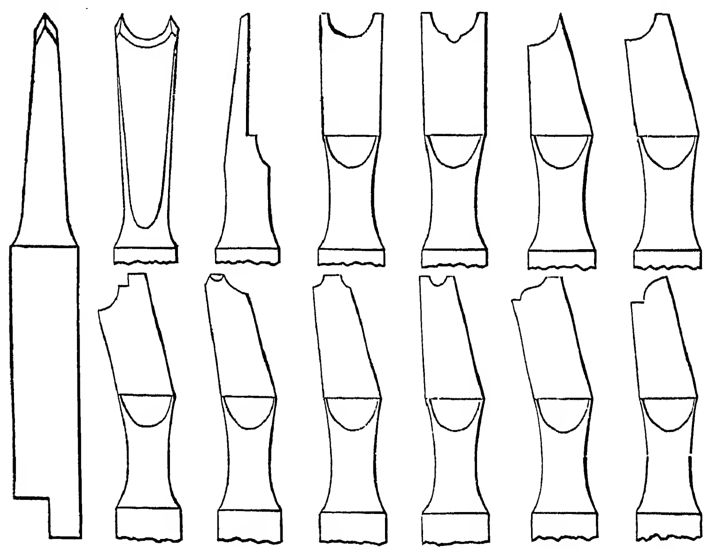
provided with an assortment of piercing drills for small holes, to be used upon such small works as can be presented to them held in the fingers.

In grinding with fig. 74, upon the brass cones fed with flour emery and oil and in subsequently polishing the concave cutting edges of the tools upon the iron cones fed with crocus and oil, the hand bead tool in its wood handle, or the sliderest bead tool in the socket handle, fig. 18, Vol. V., or the bead drill or cutter placed in their appropriate holders, and these holders fixed in the socket handle, are held face uppermost and near to their cutting ends between the two first fingers and thumb of the right hand, the thumb on the face of the tool; and are applied *above* the cone grinder with the shaft of the tool inclined from the operator and over the little lathe head, to the extent that will give the cutting bevil of the tool. The hand bent upwards from the wrist rests on the surface of the wood-tee to obtain all possible steadiness, so as to grind one uniform bevil all throughout the curved edge, and under these circumstances the attainment of the latter is assisted by the weight of the overhanging handle, which greatly aids to keep the shaft of the tool at one and the same inclination during the grinding, and further, tends to prevent the hard keen edge as it is produced on the tool from cutting into and damaging the softer cone grinder. The tool may be held quiescent upon the latter, which is more usual with the smaller bead tools of all kinds, or, especially for the larger from about one quarter of an inch wide upwards, it may be gently oscillated upon the grinder by being moved thereon after the manner of an inverted pendulum, except that its inclination towards the little lathe head has to be carefully maintained throughout its oscillations, which latter assist in equalising the facial form and the cutting bevil of the curvature. The cones are roughened by drawfiling in respect of their length to retain the oil and powders, but these, nevertheless, continually work up the cone away from the tool during the grinding or polishing, the point of a finger of the left hand is, therefore, frequently passed along the under side of the cone to replace them. It may be repeated that, the tools are first ground on the brass cones fed with flour emery and oil, then wiped clean of all trace of the powder and polished on the

iron cones with crocus and oil, and they are always applied with the face toward the small end of the grinders.

Figs. 78 to 93 represent, of about twice their actual size, a few varieties of drills used for ornamental turning; the concave portions of the cutting edges of all these are sharpened with fig. 74, and the general manner in which they are applied to the cones will be understood both from the previous and following paragraphs.

FIGS. 78. 79. 80. 81. 82. 83. 84.



85. 86. 87. 88. 89. 90.

Figs. 78, 79, show the older form of bead drills used for studding the work with little hemi-spheres or pearls. These particular drills are sharpened from both faces upon the obtuse cone grinder, fig. 77, to leave the cutting edge diametrical to their axis of revolution, or in the center of the thickness of the blade, in the same manner as in the soft wood hand-turning chisel. Their action is rather that of scraping than cutting, and this form of edge has disadvantages in not being very permanent and in being rather difficult to grind to precise diametrical truth; hence, although valuable for tortoiseshell and some similar materials, this form of edge has been generally abandoned in favour of that shown edgewise, fig. 80,

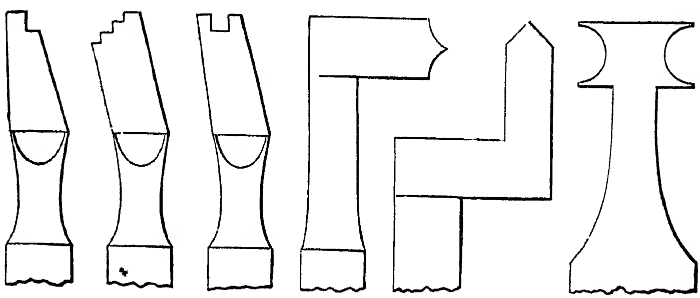
for all ornamenting drills; which are now ground from the one face only, the other and plain face being in the diametrical line of the tool.

The system of grinding the cutting bevils from the one face only secures the opposite results in both of the above particulars, and it allows the unsharpened face of the drill to remain in the diametrical line, as originally constructed. This latter condition is essential to the correct action of these tools, for should this plane, the actual cutting edge, be in the least degree removed from the center of rotation, it prohibits the smooth surface finish and lustre of all studded or traversed fluted cutting; and if the fault be still more pronounced and the face of the drill decidedly removed from the axis of rotation, the tool in studding then leaves a small portion of the material untouched in the center of its cut. It is mainly to secure this accuracy that the drills require to be made in the particular drilling instrument in which they are to be used, and to retain it, that they are never sharpened on the face, an error which at once destroys their perfect action. The most that is done to the face is to remove any slight burr that may possibly be thrown up upon it by the cone grinding; in such case the drill is removed from its holder and its flat face is laid down and held under the tip of the forefinger on the surface of the metal grinding tablet of the goniostat, fig. 64, upon which it is gently rubbed, at right angles to its axis, until the burr is *felt* to have been removed, but stopping far short of any reduction of the flat face itself, after which the cutting bevil is polished on the iron cone.

In the bead drills and in the astragal drills, fig. 81, which are ground from the one face only, the one half of the semicircular cutting edge is not only inoperative, but it rubs upon instead of cutting the work; with the larger of these drills from about ·30 to ·50 wide, measured across their ends, the friction becomes an evil, setting up heat in the work and tool to the damage of both. These larger drills, therefore, act much better when their cutting edges are made as quadrants only, to thus entirely remove the non-cutting half, something like fig. 84, but with the lower termination of the quadrant about in the axis of the stem, instead of the flat at its upper end as shown in that figure; and such quadrants are

sharpened with equal truth and facility on the cone grinders as when the whole semicircle is present. The semicircular edge, however, is advisedly retained for all the smaller size bead drills for the assistance it affords in grinding them to truth of profile; with these small drills also the friction of the non-cutting half of the edge is but little felt and may usually be neglected, but it is nevertheless good practice after the true semicircular edge has been ground in the tool, then to let the grinding fall for a few moments upon the non-cutting half alone, by pressing that upon the cone, and the slight relief from friction thus afforded is quite appreciable in its results upon the work. After the completion of the grinding and polishing on the cones, the side angles of the bead tools and the square ends of the astragals are ground and polished in the goniostat.

91. 92. 93. 94. 95. 96.



The restoration of the cutting edges of the quarter hollow drills, figs. 83, 84, and of the moulding drills which are partially concave, convex and in fillets or steps, figs. 85—90, shown in all their varieties, figs. 153—168, Vol. V., and again that of the step drill, fig. 92, is effected first as to their concaves on the cone grinders, and then as to the other portions of their edges with small parallel slips of Arkansas or Turkey oilstone of square, rhombic and triangular section and with others having rounded edges, delicately applied to them in the fingers after the manner of files. The drill in its holder with that in the socket handle is held at rest in a sloping position against a notch in a piece of hard wood in the vice, and the appropriate oilstone slip is rubbed up and down in a straight

line against and around all parts of the mixed form of the cutting edge. Few of these tools admit of being sharpened, except in part, upon the cones; concaves which abut upon fillets as in figs. 84, 85, and 87, are sharpened upon them to better maintain their forms, but with a returned curve as in the ogee of fig. 89, the most that can be done is to lightly touch the concave half of the curve upon the cone as an assistance before working the convex half into it with the oilstone slip.

The extreme flat ends of all cutters and drills of which many of figs. 81 to 93 give examples, however, are invariably sharpened truly square across in the goniostat, subsequently to the renovation of the other portions of their edges, to ensure their cutting a flat surface at the bottom of the recess they make in the work, or, if it be desired that this portion of the tool should cut an obtuse cone, the ends are sharpened with the socket of the goniostat placed at the appropriate angle.

For step drills, fig. 92, and for the similar fillets in the moulding drills, the edges of the oilstone slips are kept keen and true by occasionally grinding their surfaces on the grindstone or by rubbing them on emery paper laid flat on the bench, and it is convenient to have some of these slips of slightly rhombic or triangular sections, so as to be able to sharpen either the upright or horizontal face of a fillet quite into the corner without touching its neighbour. Small, straight metal bars charged with flour emery, oilstone powder or crocus and oil, are sometimes used after the oilstone slip, and, like the metal laps, longer retain their shapes without deterioration; they are made of soft brass of square and round edged sections, drawfiled on their surfaces, and are used in handles.

The side and bent cutters for the drilling instrument, figs. 94, 95, are sharpened in a similar manner, some on the cone grinders, some in the goniostat, and others by hand with the slip stones. The sliderest tool, fig. 96, employed for turning rings in hard wood and ivory, is sharpened first on the cone grinders and then as to its square cutting terminations in the goniostat. In this, the two semicircular cutting edges are ground to the same size and *exactly* opposite to one another; so that when the tool is fixed in the sliderest the left hand edge may be used to cut a bead within the end of a tube,

the first half of the ring, after which the second half is cut and the ring completed by the right hand edge of the tool applied outside the tube. The rectilinear motions of the sliderest ensure that the two beads are in the same plane, hence so soon as the two beads meet, the perfect ring is set free.

Moulding tools employed in the sliderest, figs. 44—47, Vol. V., are exempt from the rule against sharpening on the face which applies to all cutters and drills for ornamental turning. In the first place their figured cutting bevils are saved from wear, as much as possible, by the practice of first turning the moulding on the work to approximate shape with other tools, before they are applied to complete it; and the keenness of their cutting edges, formed by the meeting of their flat upper surfaces with the bevils of their figured profiles, may be readily renewed by rubbing the end of the flat face of the tool by hand, transversely, when laid down on a truly flat oilstone or on the tablets of the goniostat. More than this is seldom required unless the tool has been allowed to become much blunted; and the reduction of the height of the face of the sliderest moulding tool is comparatively unimportant, even if from frequent and vigorous re-sharpenings it has become "nicked in" across the end, in the manner described for sharpening screw tools, page 520, Vol. II., because the height of center can always be restored by means of the elevating apparatus of the sliderest in which they are employed. With the hand moulding tools the necessity for height of center as to their faces is met by varying the inclination at which the tool is held on the tee rest; but with either variety of tool it is requisite that the sharpening, whether trivial or carried to the extent of nicking in by many repetitions, should be so conducted that the portion sharpened down remains parallel with the original flat face of the shaft of the tool, to maintain the cutting angle. Damage to any portion of the figured bevil is not so easily recovered; when of small extent, the profile may be restored with slips of oilstone or with the small straight metal grinders, page 253, fed with emery and oil, or still better with a counterpart grinder, a moulding turned with the tool itself when in its pristine condition in brass or even on a

piece of boxwood, to be kept for subsequent use and charged with emery and oil; but by either method the tools necessarily deteriorate and depart further from their original figure at every such restoration.

A series of the small corundum wheels of square and round edges of different widths, separated by stout collars interposed and mounted upon one arbor to run in the lathe, see Catalogue, Corundum, article 3, may be employed for repairing accidents in the bevilled edges of hand moulding tools. Every member of the moulding is then treated separately, the hollows and convexities are first twisted about against the edges of the corundum grinders most appropriate to their dimensions, with the tool supported on the tee of the hand rest, and the progress on the chamfer examined from time to time to keep as near as possible to the original conformation; after which the tool is advanced to the square edged wheels to complete the straight edges of the fillets and corners. It should be remembered that, even the finest grained corundum wheels grind far more greedily than the brass and iron cones charged with emery and oilstone powders, hence the grinding must be conducted with a steady hand and but light pressure if it be intended to use the tool directly from them; the polishing of the cutting bevils, however, is then still wanting, so that the best practice is to repair the tools upon the corundum wheels and then to employ the cones to finish and polish the bevils of every member of the moulding.

Many tools from their complex forms or other reasons do not admit of being sharpened by the ordinary grinding processes, and it is frequently necessary to resort to the file for restoring their edges. Those tools that are left only of a moderate degree of hardness such as the saws, brace bits, and some circular cutters for wood and brass, may be filed without having been previously softened, other tools are lowered in temper just enough to admit of the action of the files, and still retain sufficient hardness to be tolerably durable when applied to their work; but such tools as cannot be ground and yet are required to possess considerable hardness, are softened prior to the application of the file and are subsequently rehardened: these processes have been already explained in the first volume of this work, but as there mentioned, the less frequently steel

is passed through the fire the better, as its brittleness becomes thereby materially increased.

The fixed moulding cutters used in the large planing machines for wood, are frequently sharpened upon revolving laps with rounded edges. The tool is twisted about to expose all parts of the chamfer to the action of the lap, a method which is still more manageable with tools for large mouldings. Sometimes a circular piece of oilstone turned to a round edge is used for finishing, but the difficulty of obtaining the oilstone in sufficiently large pieces and the numerous hard and soft places in the stone, prevent this from being so effective a tool as might at first be supposed. When the forms of the moulding cutters become much depreciated, it is the better practice to resort to the use of the file.

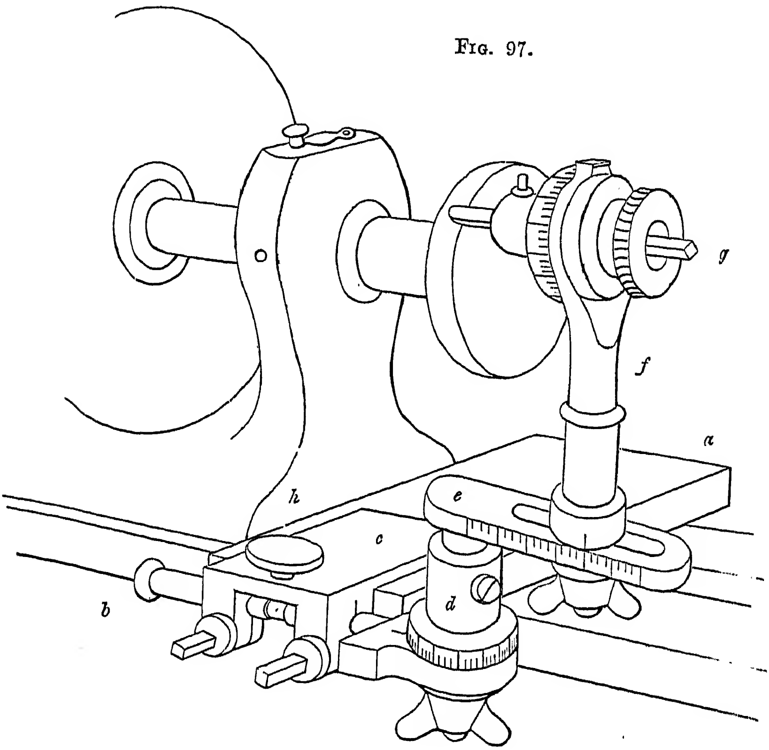
Figured cutting punches for cloth, leather, and paper, and also envelope cutters, are sharpened with oilstone slips. When they are worn down so as to become so much thickened as to render the sharpening very tedious, they are sometimes thinned by grinding them on rounded laps, but it is better that they should be softened and filed to their original forms. Circular cutting punches such as figs. 938 to 941, page 928, Vol. II. are softened and turned in the lathe, and the edges are sometimes made a little keener by holding a piece of oilstone to the chamfer of the punch as it revolves.

Convex edged tools, the reverse of those lately considered, such as the sliderest round tools, figs. 20, 29, or 36, the similar shaped cutters, and the round or fluting drills, fig. 146, Vol. V., all difficult to sharpen to accurate forms by hand, are ground to correct circular curvatures and uniform regular cutting bevils in fig. 97, an apparatus contrived by the late Mr. F. Priestley; some of whose numerous additions to apparatus for ornamental turning are mentioned in the following volume.

The apparatus for grinding round tools and drills, fig. 97, consists of a base plate *a*, to fix down on the lathe bearers by the bolt and nut of the ordinary hand rest, immediately beneath a fine emery grinding wheel, one of the vulcanite variety by preference, about half an inch thick by from four to five inches diameter, revolving on a chuck on the mandrel.

The front end of the base plate carries a horizontal round spindle, *b*, turning easily in the two bearings of a bracket, *c*; its freedom of movement in this respect controlled by two capstan-headed binding screws which compress the bearings.

Fig. 97.



The end of the spindle, *b*, carries a circular movement, *d*, terminating above in a horizontal arm, *e*, which supports a vertical pillar, *f*, at right angles to which at its upper end the tool is placed for grinding. The tool receptacle itself has a rectangular aperture the size of the stems of the small sliderest tools; these are placed in from the front and fixed by a binding screw above, and the cutters and drills, when in their appropriate holders, figs. 66, 67, are placed in and held in the same manner, all with the face of the tool uppermost.

In adjusting this instrument for use, the tool is first placed in the receptacle with the axis or center of the arc of its cutting edge fairly over the axis of the circular movement, *d*, effected

by sliding the pillar, *f*, along the slotted arm, *e*, and clamping it by the screw and nut below. The arm, *e*, is then brought round parallel with the edge of the base plate, *a*, and the whole is tilted over on its center, the spindle, *b*, until the cutting end of the tool rests upon the edge of the grinding wheel, at present without motion. If the tool to be sharpened be one already of correct form both as to the dimensions and shape of its cutting edge, this first rough adjustment is then tested by partially rotating the circular movement, *d*, by the pillar, held between the finger and thumb; and corrected, by increasing or reducing the projection of the tool through the receptacle, until by trial, the entire round cutting edge is found to bear upon the edge of the grinding wheel. Tools much worn so as to have become irregularly shaped, are either ground throughout from this first tentative adjustment, or they may be partially so ground, after which, if it appears desirable, their projection may be slightly increased or reduced to complete their sharpening to the required radii. To grind a tool to any determined radius, say that of two-tenths of an inch, the pillar *f* is first clamped at two-tenths from the zero of the graduations marked on the arm, *e*, and it is then only necessary to project the tool when that is clamped in the receptacle above, just enough to allow sufficient material to permit the formation of a continuous semicircular edge in the subsequent grinding.

In using the instrument, the edge of the tool is first prevented from more than light contact with the grinding wheel, by the finger and thumb of the right hand holding the pillar, and, so soon as this light contact is felt, the thumb screw, *h*, is turned by the fingers of the left hand to fix the spindle, *b*, to retain the apparatus at the inclination so given. After which the entire edge of the tool is swept round on the wheel, moistened with oil and now put in revolution towards the operator, by moving the pillar from side to side held by its round portion. This suffices for the renovation of a tool the cutting edge of which is already of its true shape, radius and cutting bevil. For those tools which from bad shape or condition require further grinding, the thumb screw, *h*, is then slackened and the tool allowed to again rest on the wheel by the weight of the apparatus, which gives a slightly increased

inclination, and with the spindle again fixed by its binding screw, *h*, the grinding is continued; this procedure is repeated so far as may be necessary, until the edge of the tool is reduced to its true curve and radius; and also, by this system of gradual reduction, the edge of any tool is readily and certainly ground to any required radius, whilst, as the edge of the tool meets the circumference of the wheel some way above the axis of the latter, it receives a keen cutting bevil.

It should also be mentioned that during the grinding, the entire length of the circular cutting edge of the tool, as it sweeps round upon its axis, bears only upon one point or line around the circumference of the revolving wheel; and for this reason the central and reduced portion of the horizontal spindle, *b*, held by the binding screw, *h*, is made of a width just greater than that of the edge of the wheel, to permit the apparatus to be fixed with the tool applied to any point across the edge of the wheel, so as to equalize the wear upon its grinding surface.

Some further particulars in the construction and use of fig. 97, beyond those for grinding round tools, are as follows. The edge of the circular movement, *d*, is sometimes graduated in degrees read by an index line below, the zero of the divisions being in the line of the arm, *e*; and the circular movement, *d*, may be firmly fixed at any point of its rotation by the screw and nut underneath. With *d* fixed at zero the apparatus may be used for grinding flat-ended tools, drills and cutters, and when fixed at the appropriate angles to either side of zero, for grinding similar single or double angled tools. When employed for these rectilinear edges, the binding screw, *h*, is withdrawn to stand clear of the spindle, *b*, and the two screws in the bearings of the bracket, *c*, are slackened, to allow *b* a free endlong traverse, that the edge of the tool may be gently carried to and fro across the edge of the revolving wheel throughout its grinding. It must be admitted, however, that fig. 97, admirable and in every respect satisfactory upon round edged tools, does not give such perfect results as the goniostat, fig. 64, in sharpening rectilinear edged tools; but leaves their edges too rank and without the polish and second facet, already described as so necessary to these tools for satisfactory brilliant cutting in ornamental turning. Rectilinear

edged tools sharpened by the one or the other of these instruments show a marked difference in the quality of the work upon which they are employed; and when prepared in fig. 97, have to be completed and polished in the goniostat.

The tool receptacle is also generally provided with a graduated circular movement, as shown in the figure, read and fixing by a milled head in like manner to that at *d*. The two are very useful for grinding pointed tools formed by the meeting of several facets, which, like one example, the triangular pointed tool, described p. 586, Vol. V., are employed for tracing fine and equal lines for ornamental patterns on coloured cards, or on wood or metal blocks for printing. In producing these delicate points, the circular movement, *d*, is set for the angle, and the divisions of the upper circular movement give the number of the facets; which are ground one after the other, the tool lightly applied to the grinding wheel in the position shown by fig. 97, the spindle, *b*, only just sufficiently free to rotate, but without endlong traverse.

Tools with long conical points which, like the last named also, are employed for tracing patterns through non-actinic films on glass for photographic printing; are produced by fixing the arm, *e*, when set over to the right hand at the appropriate angle, by the screw below, *d*, so as to apply the cone point lengthwise across the edge of the revolving wheel; and then with the upper circular movement just sufficiently free to rotate, gently turning the tool by a winch handle placed upon a square shaft which projects from the rear of the receptacle.

SECT. III.—GRINDING, SHARPENING AND SETTING THE TEETH OF SAWS.

THE practice of sharpening saws by hand has been already fully explained, pages 688 to 698, Vol. II.; it remains to describe some appliances used as aids to the file, and the general characteristics of the machines in which the file is replaced by revolving emery wheels.

Among the former the vice, fig. 98, is intended to maintain one uniform vertical and horizontal inclination of the file throughout its operation upon every other tooth, a matter of

difficulty to those unpractised in saw-filing. It consists of a pair of straight iron jaws, about sixteen inches long by three or four inches deep, connected together above by arched-shaped pieces at the ends; the half of each arch jointed or notched at the top into its fellow and in the solid with its jaw. One jaw is screwed down to the bench, the saw-blade is placed between the pair, teeth uppermost and parallel with their upper surfaces, and the loose jaw is brought up to nip it by screws which pass through the arched pieces. A round rod parallel with the jaws terminates in short equal arms by which it circulates upon pivots on the ends of the loose jaw, upon which it may be placed higher or lower and then fixed by thumb screws; and a flat plate that slides freely along the

FIG. 98.

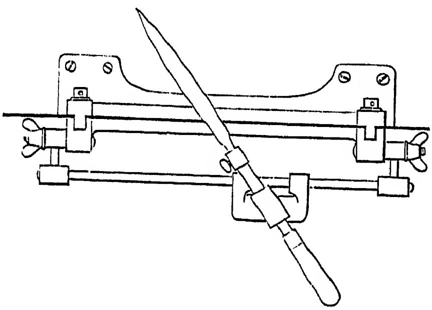
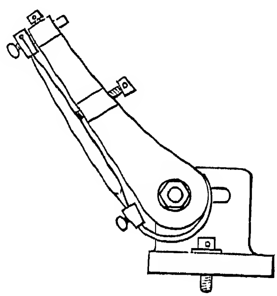


FIG. 99.



rod carries a transverse socket, which latter may be fixed by a screw below the plate to stand at any horizontal inclination to the saw-blade. The socket is pierced with a rectangular mortise for the file-holder, a corresponding smooth bar with a taper hole and a binding screw for the tang of the file at the one end and a handle at the other. The vertical and horizontal inclinations adjusted, and maintained by the rod and socket, the file resting on the saw is used in the ordinary way on every other tooth with its point between the thumb and two first fingers to give the pressure, the holder sliding within the socket at every stroke; after which the horizontal inclination of the file is reversed to sharpen the intervening teeth. A few teeth next to the handle of the saw cannot be reached, and if required, these have to be filed with the blade in an ordinary vice.

Various machines have been constructed to employ a file after this manner automatically upon both rectilinear and band saws, in which the teeth are also generally too small for the satisfactory use of an emery grinder. All these machines have a horizontal slide, usually attached to the uprights on one side of the frame and placed a little below the level of a platform by which the latter is surmounted. The jaws for rectilinear saws travel along the vertical face of this slide, and are propelled from point to point either by a long screw actuated by a ratchet-wheel and detents, or, more frequently, by a paul or finger which passes over one and engages against the face of every other tooth of the saw itself. An ordinary triangular saw-file is used, held by both ends in a frame, which latter is reciprocated on a transverse slide on the surface of the platform; the file rests on the saw-blade and its holder is adjustable within the frame both for the horizontal angle of the teeth and downwards for the depth of penetration, the holder also passes up an inclined plane or is lifted by a cam to raise the file clear of the tooth at every back stroke, during which the saw receives its intermittent automatic advance.

Band-saws are laid down teeth uppermost, passed around two horizontal flanged wheels, mounted one at either end on the surface of the platform, one of which wheels is adjustable by a screw to give the band-saw a moderate tension. The file and its slide remain as before, but the long jaws are replaced by very short ones which have no traverse. A rod attached to the outer of these jaws passes through the inner and is actuated by an adjustable eccentric below the platform, this alternately brings the jaws together to nip the band saw whilst the file is acting and just releases them for the back stroke, during which the saw is carried forward through the space of two teeth by the before-mentioned paul or finger.

The process of topping or reducing the points of all the teeth in straight saws to one level line, to ensure that every tooth acts equally upon the work, is frequently required prior to the sharpening, and is executed with the flat side of the file laid along the teeth as described, page 690, Vol. II. The wear upon circular saws causes them to suffer some loss of circumferential truth, they are also liable to the accident of broken

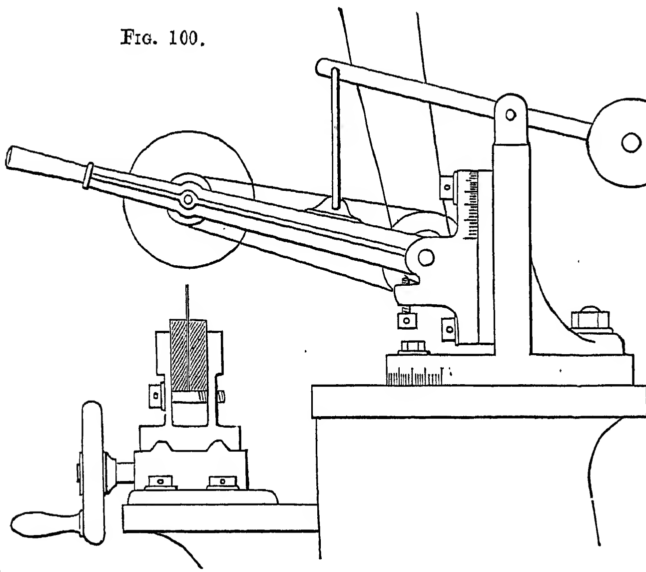
teeth and they, therefore, require to be topped from time to time that their peripheries may be everywhere true before the teeth are resharpened. When the saw is of moderate diameter the correction may be made with the file with the saw on its spindle running between the centers of a lathe; but as the file rests on only one spot of its surface if held still on the revolving serrated edge beneath it, or only on a short line on its surface if traversed from the operator, it is rather difficult to hold with sufficient rigidity to prevent its riding on the saw and following in place of correcting the want of truth. Hence the file is frequently discarded and the topping done with a graver, the tool is very firmly held on the hand-rest supported on one of its under corners on which fulcrum the point is cautiously advanced until it has reduced the length of the more prominent teeth and then that of the others until all are truly circumferential, the saw revolving the reverse way to when it is in use.

Large circular saws are usually topped in the machines in which they are employed; the turning tool is then inappropriate and it is still more difficult to attain truth in the teeth with the file than with those of small diameter. The transferable apparatus, fig. 99, patented by Mr. J. Wootton, 1890, retains the file in the position in which it is fixed on the revolving saw. The base, a long wide iron bar, seen endwise in the figure, is clamped down by screws through slots at each end which pass into holes tapped along the frame of the machine or in the sides of the saw table; a vertical wing on the bar pierced with a horizontal mortise carries an arm clamped to it by a bolt and nut, and the file is held in sockets at the front edge of the arm. The upper socket is adjustable and the lower for the tang of the file is attached to the end of a strong steel spring, curved and fixed around the base of the arm, and the elasticity afforded by this arrangement is controlled by a set screw which bears on the file. The arm is pressed down by hand on the slowly revolving saw and then clamped, and the wear on the file is distributed by occasionally shifting the arm and the base upon their fixing screws by their respective slots.

Emery wheels of appropriate form of edge are used for hollowing the backs and sharpening the faces and tops of the

peg, the different varieties of hand-saw shaped and cross-cutting teeth and the gullet teeth of the larger saws, the forms of which teeth are shown by the diagrams, page 684, Vol. II. The wheels vary from about 12 inches to 15 inches diameter and from one-eighth to three-quarters of an inch in thickness, their peripheries round or angular according to the shape of the tooth required; usually one wheel suffices to sharpen both the face of one tooth and the back of its neighbour simultaneously, but in some cases, as for gulletted teeth, two are employed one after the other, a

FIG. 100.



round edged wheel for the intervals and one with a flat edge at an angle to its sides for the tops of the teeth. The spindle of the emery wheel is mounted to run in some form of pivotted swing frame by which the wheel is depressed to grind and then lifted off every tooth of the saw which travels beneath it; the modes of mounting and driving the grinding wheel and of traversing the saw from point to point somewhat vary, but the diagram of a hand machine for moderate sized rectilinear and circular saws, fig. 100, shows the necessary powers.

The two ends of the forked arm carrying the emery wheel are pivotted to the ears of a large ring, graduated on its upper

edge in degrees of the circle, which is bolted to a circular fitting on the vertical face of a strong bracket, and the bolts pass through curved mortises in the ring so that the latter and the arm upon it may be shifted round either way and then fixed to give the vertical inclination of the grinding wheel; the broad base of the bracket is also graduated upon its semi-circular front end, and moves round upon the main bolt by which it is secured to the pedestal of the machine, to thus place the emery wheel to the differing horizontal or transverse angles required for the face of the tooth. The upper end of the bracket carries a lever with a link or chain to the arm and a counterpoise which raises the wheel from the saw, and a vertical screwstop in a projection on the ring abuts against the under side of the swing arm and determines the extent of its depression during the grinding. The speed driving pulley runs on the axis upon which the arm is pivotted, so that the bands remain at one tension whether the arm be raised or lowered; and the emery wheel is sometimes provided with a sheet iron guard surrounding a part of its circumference fixed near the handle of the arm.

Straight saws are held between wood bars to absorb vibration, the wood and saw are clamped together by bolts which pass through the vertical uprights of long horizontal iron jaws, the latter attached to a corresponding slide below that is moved by a rack and pinion, the whole carried on a bracket on the front of the pedestal of the machine. Circular saws, placed between discs of wood, are clamped on the end of a short spindle which may be fixed at different heights, according to their diameter, on the face of a vertical slide which replaces the jaws and rack and extends from the top of the bracket to the floor. The saws in either case are moved from tooth to tooth usually by a ratchet worked by hand, and every other tooth is first sharpened and then the emery wheel is readjusted to stand at the opposite angle to proceed over those intervening.

In large sawmills where saw sharpening is perpetual, the machines for the purpose follow the general character of fig. 100, but are otherwise automatic, and they are frequently arranged to grind every tooth one after the other, their faces to right and left alternately. The swing arm is usually lengthened to extend both ways from the support upon which

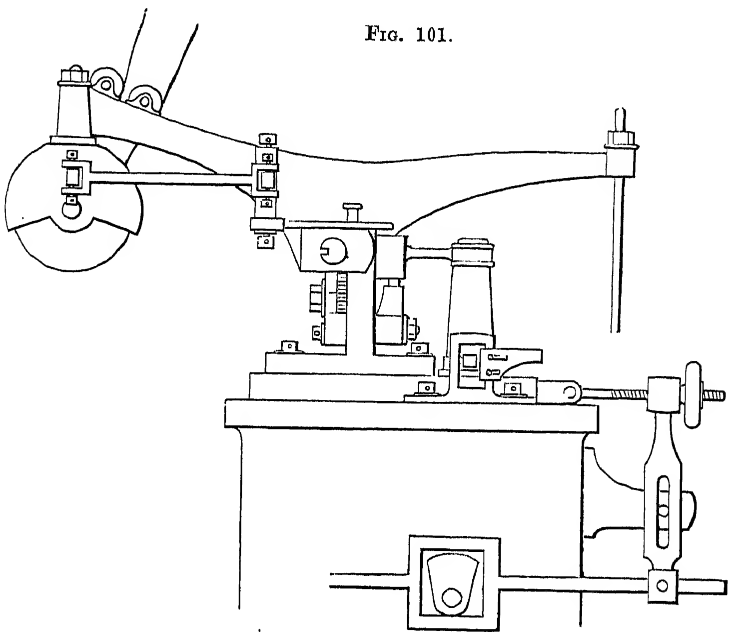
it moves, and the one end is connected by a link to an eccentric on a shaft below to raise and lower the wheel and to dispense with the rod and counterpoise. The same or a second shaft actuates the mechanism for the feed or advance of the saw from tooth to tooth. Occasionally the arm, with the emery wheel adjustable upon it for the vertical angle of the saw tooth, swings in a bracket fixed at right angles to the line of traverse of the saw, and the jaws and saw throughout their traverse are made to oscillate to the right and then to rest, and then in like manner to the left, for the few moments required for the grinding of every succeeding tooth, on a point immediately under the vertical diameter of the emery wheel when lowered; all of which movements are made to agree as required with various dimensions of teeth, and to more or less synchronize, by the adjustments of the ratchets, levers and eccentrics by which they are effected. In the alternative arrangement, usually preferred as more stable, the saw travels and is arrested from point to point in a straight or circular path, and the bracket of the swing arm oscillates on a center to give the transverse angles, and rests during the grinding of every tooth.

The process is differently effected and the emery wheel is traversed across the saw in a machine used in Germany, patented by Herr F. Schmaltz, 1889, the main portions of which are indicated by fig. 101. The swing arm is pivotted by a fork which projects below the middle of its length to the usual piece that moves round and is fixed on a circular fitting on the upright face of the bracket, to give the emery wheel the vertical inclinations required for the face of the teeth. The wheel runs in a case with flat sides which rotates within determined limits on a vertical pivot at the end of the swing arm, and the latter is raised and lowered by a rod at its other extremity connected to an adjustable eccentric on a shaft mounted in the frame of the machine below. The base of the bracket is fixed to the surface of a cross slide on the table of the machine, which is reciprocated to traverse the emery wheel to and fro across the saw blade by a cam working within a rectangular frame on a horizontal bar below; the end of the bar is jointed to a vertical slotted lever and the traverse of the slide is regulated by a nut and hand wheel which determines the position of the upper end of the lever

upon a screwed shaft attached to the slide. The transverse angles of the emery wheel to the saw blade, and the alteration of its position from right to left for every alternate tooth are given as follows :—

One end of a straight rod moves on centers on a projec-

Fig. 101.



tion on the case of the emery wheel and its other extremity on similar centers on a projection on the vertical half of a bell-crank mounted on the swing arm; the horizontal arm of the bell-crank is slotted and is moved by a pin on the surface of a block, which latter travels lengthwise on a short round shaft a prolongation of the axis of the swing arm. This block is reciprocated on its shaft by a second or slide block pivotted to its rear face and travelling transversely on the back of the bracket, and an upright arm jointed and fixing at vertical inclinations to the rear side of the bracket, enters a slot in the under side of the slide block to support it during its traverse whatever angle may be given to the swing arm and the block on the shaft by the circular fitting to which the arm is pivotted. The slide block is moved to and fro by a right angled lever the two arms of which are attached to the ends of a sleeve working

on a post fixed on the slide behind the bracket; and a stop adjustable in the width of its opening and as to the position at which it may be clamped on the table of the machine with respect to the traverse of the cross slide that carries the bracket, receives the end of the lower lever on the sleeve and, by the reciprocation of the slide, actuates the whole system to more or less turn the emery wheel to right before it passes across one tooth of the saw and to left before it returns across the next.

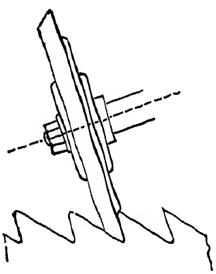


FIG. 102.

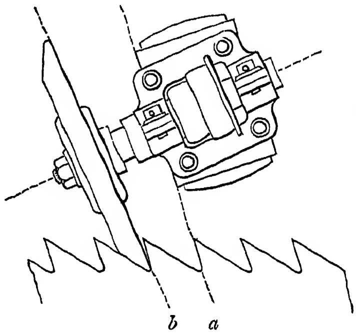


FIG. 103.

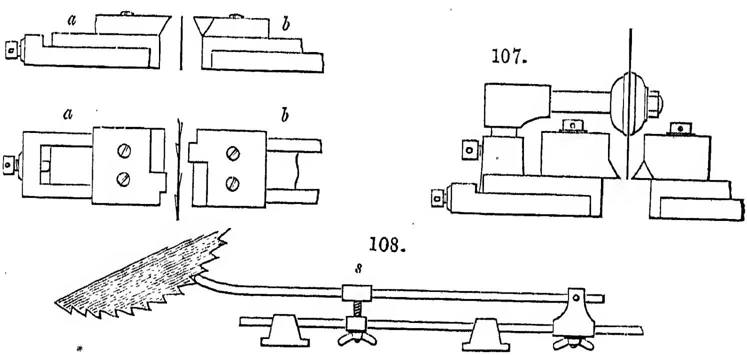

FIG. 104.

The emery wheels in all these machines wear away rather rapidly, a difficulty met by frequently reinstating the forms of their peripheries by turning them with a carbonate diamond tool, until they become too small in diameter and are replaced. The wear on the face or edge of the wheel is as great but is less prejudicial than that sustained by its flat side, which, from constantly passing down the faces of the saw teeth, gradually loses its sharp arris and eventually wears into a rebate, as shown in an exaggerated degree, fig. 102; and if this increasing deterioration be neglected, the wheel then more or less rounds the tops of the saw teeth, as shown in fig. 102, instead of grinding them to their true keen angles. To partially overcome this difficulty, Mr. L. P. Halliday of Chicago, U.S.A., in a machine patented in 1889, mounts the spindle of the emery wheel with a power of adjustment across the end of the swing arm. The latter is placed to descend at the angle required for the face of the tooth, the line *a* in the diagram, fig. 103, and the spindle of the emery wheel is adjusted to place the side of the wheel at a little greater angle

than that of the arm, as shown by the line *b*; the side of the wheel, therefore, is not in actual contact with the face of the tooth which is traversed by the descent of the arris alone, and the wear on the side of the wheel is reduced or nearly avoided.

The process of *setting* saws or bending their teeth equally and alternately to right and left, so that the extreme points on either side stand all in a straight line and collectively form an edge a little wider than the thickness of the saw blade, is necessary to give the latter some clearance to prevent its binding within the material it is cutting, and is performed with nearly every variety of saw after the sharpening. Setting is usually and for the smaller saws invariably done by hand, the tools used and their application are described, page 696—8, Vol. II., and the gage, fig. 104, a piece of sheet steel notched out to the extent to which the tooth is to be bent and applied against the side of the blade by its straight edge, is of assistance in setting large saws. The larger rectilinear, band and circular machine saws are also set by mechanical appliances, generally of a simple character but sometimes automatic, and, as in the example of the latter kind indicated by the diagrams figs. 105—108, part of a Swiss machine patented by Herr H. Landis, 1890, the apparatus is often mounted on the table of the machine in which the saw is previously sharpened.

FIGS. 105. 106. 107. 108.



A slide across the table of the machine is provided with two strong iron blocks one of which, *a*, has a small power of endlong adjustment, but when in use is stationary, and the other, *b*, is reciprocated and nearly into contact with *a*, by a link and

a variable eccentric; and the surfaces of these blocks carry removable steel jaws, notched to agree with the dimensions of the teeth upon which they are to be employed and bevilled reverse ways to the slope to which they are to be bent. Straight saws placed within guides and band saws stretched around adjustable horizontal wheels at either end of the table, travel between the blocks and are advanced to the extent of two teeth at a time by a paul or finger on the end of a rod which rests on their teeth, the rod reciprocated horizontally. The forward motion of the block, *b*, occurs during the return movement of the paul, which latter then only slips over the backs of two teeth, and the blade is gripped at the same moment by the vertical faces of the blocks *a* and *b*, and the jaws attached above them set or bend the two teeth opposite ways.

Circular saws are mounted on the end of a short bent horizontal arm on the top of an upright, fig. 107, which latter is raised and fixed, according to their diameter, in a socket mounted on the table of the machine near to the cross slide. The saw is turned on its axis through the space of two teeth between every grip of the jaws by the reciprocating rod previously mentioned, but the paul used for straight saws is removed and replaced by a second rod, fig. 108, jointed at one end on the first and curved upwards as a finger at its free extremity, near to which the two rods are pressed apart by an adjustable spiral spring. When advanced by the eccentric moving the lower rod, the finger engages against the face of a tooth and rotates the saw through a space equal to two teeth, and compresses the spring *s*, and on the return movement the finger slides along the back of the tooth above it and when free is raised by the spring the height of two teeth, ready for its next stroke. As the periphery of the saw is above the slide, the jaws are deeper and are placed the other way uppermost, and their faces grip the blade whilst the projections and bevils below them set the teeth.

CHAPTER IV.

THE FORMATION OF METAL PLANE SURFACES BY ABRASION.

Throughout the figuration of materials by abrasion, the principal dependence for the correctness of form is placed upon the abrasive tool or grinder being exactly a counterpart of the form to be produced; thus for plane surfaces a flat grinder is employed, for concave surfaces a convex grinder, and so on. In numerous cases the grinder is made as a revolving wheel, figured to the required counterpart form either upon the edge or upon the side, and the work is simply held to the grinder by hand without the assistance of any mechanical guidance. In other cases the work is traversed on slides beneath revolving or reciprocating grinders; and in some few instances, where great accuracy of form is required, dependence is placed upon the relative motions of the grinder and work, both usually under the control of mechanism.

The natural grindstone, the factitious and the emery wheel are generally employed for the rough preparation of the surfaces; but are all also used with the work under mechanical guidance for the production of fairly and often very nearly true surfaces, which latter, when necessary, may subsequently be more accurately figured with metal grinders supplied with the abrasive powders. Within certain limits, it may be said generally that, the greater the accuracy desired in the surfaces to be produced the harder should be the material of which the grinder is composed, and, on the other hand, the finer the surface, or the higher the desired polish, the softer should be the grinder. These opposite qualities required in the grinder render the attainment of very accurate and, at the same time, highly polished surfaces, a point of considerable practical difficulty, as will be abundantly shown hereafter; but a moderate degree of truth, sufficing for most purposes, may be readily attained with ordinary care.

The present chapter is devoted to the grinding and polishing

of plane surfaces in metal, and is followed by others treating respectively, upon the production of plane and cylindrical surfaces in stone, on plane surfaces in plate and sheet glass, upon the figuration of cylindrical and conical superficies in metal, and upon the production of spherical superficies and lenses in glass and metal; all elementary forms which, by their combination, include nearly every figure required in the mechanical arts.

SECTION I.—THE PRODUCTION OF PLANE SURFACES IN METAL, GENERALLY OF SMALL DIMENSIONS.

Revolving laps of metal used upon their flat sides and supplied with emery and water, are extensively employed by mechanicians for finishing flat surfaces of small and medium size requiring tolerable accuracy. Sometimes the lap is employed for brass, iron and soft steel, but more generally the flat surfaces of works in these metals are wrought by the planing machine or file, and finished in the manner described in the catalogue of grinding processes, pages 77 and 78; and the lap is principally employed for correcting works in hardened steel, such as the broad flat surfaces of cutting tools, the faces of dies, hardened steel plates and numerous other objects. All these works are made nearly flat either with the grindstone, emery wheel or file, prior to their being hardened, as the general accuracy of the forms may be much more quickly produced by these means; and the lap is then chiefly resorted to for removing those slight distortions occasioned in hardening, that are beyond the correction of the hack hammer, described at page 247, Vol. I., and also for giving a smooth and finished surface to the work.

Sometimes the laps are made of cast-iron, or copper, because these hard metals longer retain their forms uninjured; but, as previously mentioned, lead hardened with a little antimony is the metal generally used for laps by mechanicians, as the yielding lead allows the emery to become embedded in its surface, and consequently a smooth face can be produced upon the work with an emery the particles of which are sufficiently large to cut rapidly. Whereas when iron or copper is employed, the emery can scarcely penetrate

the lap, but is partially lost, and the remainder rolls over and makes scratches in the work nearly equal in depth to the size of the particles of the emery powder.

Laps not exceeding a few inches in diameter, used by mechanicians, are generally mounted vertically, not upon the middle of long spindles after the manner of those used for cutlery, but screwed as chucks upon the mandrel of a lathe, as shown in fig. 71, a method adopted to avoid the interference of the spindle and to render the entire side of the lap available for works of a moderate size. Larger laps are mounted to revolve horizontally, somewhat after the manner shown in fig. 52, but in much stronger frames and generally driven by steam power, as the diameter of these horizontal laps is sometimes as much as five or six feet. The varying velocity of the surface of the lap, which continually decreases from the periphery to the center, is however very objectionable in large laps as it renders the tool much less effective near the middle, and is besides liable to cause the lap to become conical from its being less worn near the center. To avoid these interferences as much as possible, large laps are usually made as annular discs cast upon iron plates or wheels, and so as to leave a central aperture or recess of about one-third of the extreme diameter of the lap.

Emery wheels mounted in like manner to revolve horizontally, are an effective form of lap for those works which may be left with less smooth and perfect surfaces, or for preparing the work before it is submitted to the metal lap. They are usually flat annular rings from about one to three feet in diameter, with central vacant spaces as before mentioned, fixed upon iron surface chucks provided with rims cast in the solid to fit around their peripheries. The smaller sizes are frequently driven by a pair of bevilled friction wheels, one on the spindle and the other on a short horizontal shaft which also carries the driving pulley, and the whole is mounted in a dwarf iron frame to be bolted down on any convenient bench; the larger horizontal emery grinding machines frequently have the driving pulley on the spindle, and the band from the countershaft runs to it around two guide pulleys. With these larger lap wheels also, the work is sometimes held down upon the grinding surface under a flat plate jointed to the end of a

lever handle, with its fulcrum adjustable for height for work of different thicknesses, mounted upon a vertical post fixed to the framework of the machine.

In lapping small thin works the object is held between the thumb and finger nails, and placed fairly in its position on the metal lap while the latter is at rest; the lap is then put in rotation and the work is held quite steadily to its face with moderate pressure, and the lap is stopped before the removal of the work whenever it is desired to examine progress. Larger pieces that can be conveniently held in the fingers are applied to the lap while that is in rotation; the work is quickly placed in its position and the pressure is steadily applied on the back of the work, as near as convenient to its center, in order to feel when it bears uniformly upon the grinding surface; the work is retained in its position for a few seconds and then, in order to examine whether it has been properly placed, it is lifted at once perpendicularly from the face of the lap, and not gradually drawn off, as the latter course would be liable to round off its edges. Should it appear to have been incorrectly placed on the lap the work is applied in another position, but the principal dependence is placed upon the sense of feeling, as with a little practice the fingers readily appreciate when the work lies fairly upon the grinding surface.

Thin works of moderate size that are too yielding to be applied with the fingers, or those that would become too hot to be conveniently held, are temporarily fixed upon a thin piece of wood by driving two or three pins into the wood around the edges of the work, and very small objects are sometimes cemented upon a small piece of wood. In these cases, however, the flat position of the work upon the lap cannot be so readily appreciated as when the work is held directly in the fingers. Larger works may be correctly placed upon the lap without difficulty, as their size serves at once as a guide and prevents the general accuracy given by the file being accidentally depreciated.

When the work is first commenced it may with advantage, if not very small, be traversed by sliding it to different parts of the surface of the lap to equalize the wear, but towards the conclusion it should be held quiescent in one position, and then the

uniform wear of the grinder may be ensured by applying the work to a different part of the lap every time that it is placed upon it. When fresh emery is required it should be applied by preference at the commencement of lapping any object, in order that the emery may at first cut rapidly and be gradually worn finer with the progress of the work, so as to leave a smooth surface at the conclusion.

Flat works in steel, are sometimes polished on iron laps supplied with crocus, but more generally, after being lapped with fine emery, they are smoothed with flour emery paper wrapped around a file and moistened with oil, and the works are lastly polished with small rubbers, as explained on page 78. Flat works in brass are finished as described on page 24.

Facets on steel jewellery, such as beads, studs, buttons, the ornaments on the hilts of dress swords, and similar objects, are ground to form on horizontal laps, such as fig. 52, fed with fine emery, and are afterwards polished after the general method of cutlery.

The small solid beads employed in common ornaments are prepared from sheets of iron of suitable thickness; the plates are first punched in a fly-press with small holes of the proper size for the passage of the wire by which the beads are strung; the pieces of metal to constitute the beads are then punched out with a circular punch a little larger than the intended diameter of the beads, and having a small central pin that fits into the hole previously made, in order to ensure the latter being in the center of the bead. The pieces are next fixed on a pointed steel wire and rounded fairly hemispherical at each end with a file. They are then case-hardened in bone dust enclosed in sheet-iron boxes, a layer of bone dust and one of beads being placed alternately until the box is filled; the whole are then case-hardened, after the method explained, page 260, Vol. I. For cutting the facets the beads are fixed singly on pointed steel wires and applied to the horizontal lap supplied with emery and water; no guide is employed for these common beads, but the wire is held at the proper inclination and twisted in the fingers to cut the facets in succession on the one half, and the bead is then inverted on the steel point for its completion. The scratches left by the lap are removed either in the rumble described in the catalogue, or

by stringing the beads on wires and applying them to revolving wheel brushes, fed with oil and emery of various degrees of fineness; rottenstone is next employed in a similar manner, and the beads are finally polished by rubbing them in the naked hand with putty powder or crocus.

Large hollow steel beads for superior works, are raised from either the best charcoal iron, or decarbonized cast-steel plates, after the general method explained in Chap. XIX., Vol. I. The metal is punched out in a fly-press, first as a concave disc, and by alternate punching and annealing the sides are brought to the cylindrical form, the bottom is then removed, and the ends are gradually closed in with punches, leaving a small hole at each end of the hollow sphere; the beads are then roughly filed and case-hardened. The facets on the large beads of the best kind, both hollow and solid, are sometimes more exactly cut by fixing these beads on pointed wires inserted in wooden handles, which, instead of being cylindrical are made as polygonal prisms of various numbers of sides according to the numbers of facets required in the work; a horizontal wooden bar is placed at a suitable height on one side of the lap, and the flat sides of the handle are rested in succession upon it; this gives the correct number of facets to every bead, and the angle at which they are placed is regulated by the height of the bar and the inclination of the handle. The beads are lastly strung on wires, smoothed on wheel brushes, and polished by hand in the same manner as the small beads, but with more care.

Round and oval studs are in like manner punched as flat or concave discs out of decarbonized sheet steel, and rounded with the file; but before they are case-hardened the shanks are attached by soldering, and covered with small lumps of clay to prevent them from being affected by the hardening process. For cutting the facets, they are held in small hand vices or pin tongs, sometimes inserted in polygonal handles, and applied to the lap in the same manner as the best beads. For polishing the studs, they are closely arranged in a flat block covered with cement, which is softened by heat to allow the shanks to penetrate. The whole surface is then smoothed with emery and water, applied with hard flat brushes rubbed in all directions either by hand or machinery; after the emery,

rottenstone is employed in the same manner, and the final lustre is given with putty powder or crocus on the hand.

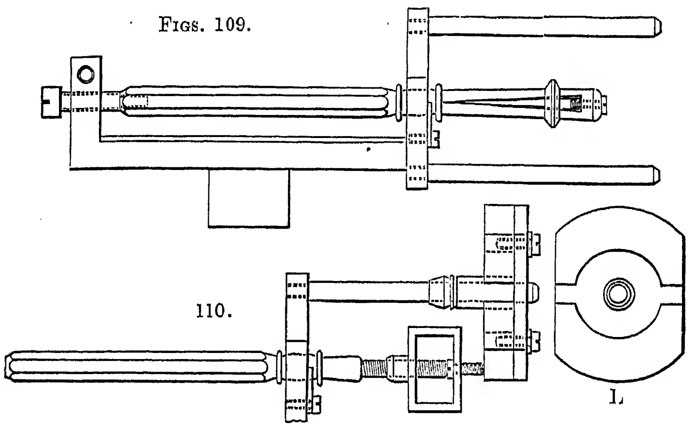
Facets on gold and silver, and the flat parts of jewellery generally, are cut and polished on revolving wheels after the same general method as that pursued by the lapidary for cutting facets on stones, but the gold cutters commonly use vertical laps mounted much after the fashion of fig. 5, in order that they may use both the side and the edge of the lap for different parts of the work. The laps are made of pewter, or an alloy of tin and zinc of different degrees of hardness according to the size of the work. They are turned very true and flat on their surfaces with the sliderest and left quite smooth.

For cutting the facets the laps are charged with fine washed emery, smoothed and rubbed in with an agate or pebble burnisher, and supplied with water. The work when too small to be held in the fingers is cemented on a small wooden stick to serve as the handle, and the position of the facets is given with the fingers unassisted by any guide. If the facets have to be entirely produced by grinding, a moderate pressure is applied when the cutting is first commenced, and the lap is driven with tolerable velocity; but as the facets become developed, the pressure on the work and the velocity of the lap are both gradually diminished. In some cases the work is smoothed and partially polished upon tin or zinc laps fed with dry crocus, or rouge, rubbed into the face of the lap with a piece of smooth agate. Separate laps are employed for gold and silver, and they are kept scrupulously free from dust; the fine particles of the materials removed in polishing become embedded in the surface of the finishing laps, and this is generally considered to assist in giving a good face to gold or silver. In other cases the work is taken at once from the emery lap to the buff wheel and smoothed with fine crocus; other buff wheels supplied with rouge are used for commencing the polishing, which is completed with small buff sticks, and the final black lustre is given with rouge on the naked hand, the soft skin on the side of the fingers being sometimes employed for delicate objects.

Fig. 109 represents a Geneva tool used by watchmakers for polishing the heads and points of small screws that are

required to be very flat and highly finished on their ends. The instrument is made as a miniature lathe head to be fixed in the vice, the mandrel is about 3½ inches long between the bearings, and is generally made octangular that it may be driven, not with a pulley and drill bow as usual, but by the friction of the left hand laid flat upon the mandrel and passed backwards and forwards as in rolling a wire, which method is sufficiently effective for the slight purposes to which the instru-

FIGS. 109.



110.

ment is applied. The front end of the mandrel is made as a pair of pin tongs for grasping the screws while the heads are being polished, and several mandrels are fitted to the one instrument to serve for different sizes of screws. For polishing the points of the screws, other mandrels shown in fig. 110, are employed, the end of the mandrel is made as a screw about three quarters of an inch long, upon which a square frame is fitted, having in the front end a small central hole through which the screw is passed to expose its point, while its head is grasped between the end of the mandrel and the inside of the square frame. To the front plate of the instrument are fixed two cylindrical pins parallel with the mandrel and about 2½ inches long. The lower pin, not shown in fig. 110, serves as a rest for the support of the hand grinding tools, or rubbers, made in shape like small flat files without teeth and supplied with various polishing powders. The screw to be polished is fixed in the mandrel, which is rotated by the

left hand, while the grinder supported upon the lower pin is passed to and fro with the right hand, exactly as in filing the flat head of a screw in the ordinary lathe.

The above method serves sufficiently well for screws requiring only a moderate degree of flatness, but for those in which great accuracy is required, the small lap shown at L, is employed. It consists of a plate of brass fixed to a tube that exactly fits the upper cylindrical pin of the instrument and to the inner side of the brass plate are affixed two semicircular plates of metal or laps, the surfaces of which are made quite flat, and exactly at right angles to the central line of the tube. There are generally two plates fitted to each instrument, each plate carrying two laps so as to make four grinders of different degrees of hardness, namely, one each brass and gun-metal, and two of iron or steel; the faces of the grinders are slightly roughened with a smooth file applied at various angles, to enable the polishing powders to be retained upon their surfaces. The screw having been fixed in the mandrel a little of the polishing powder is rubbed on the grinder, the tube is then slid over the pin, and while the mandrel is rotated the grinder is swung backwards and forwards in an arc of about one fourth of a circle. The face of the grinder being quite flat and traversed at right angles to the mandrel, the heads of the screws are ground quite flat, notwithstanding that they are polished very highly. Sometimes instead of the mandrel being rotated by the flat hand as above described, the instrument has a pulley like a drilling lathe and is driven with a drill bow; in this case one mandrel only is used, and the screws are fixed in similar grasping apparatus made as small chucks, fitted to the mandrel either by a screw or a plain conical fitting.

SECT. II.—THE PRODUCTION OF PLANE SURFACES IN METAL OF MEDIUM AND LARGER SIZE.

In many metal works of a much larger scale than those lately considered, plane surfaces are attained by grinding with emery wheels, and frequently to the complete supersession of the file and planing machine. The emery wheel has been called a continuous file, and the work is applied to it, some-

times in the hand, but with more accurate results when traversed upon, in front of, or beneath it, mounted upon tables or slides analogous to those of the sliderest or planing machine. Works which may be held in the hand have their surfaces ground upon the edge of the emery wheel as upon the ordinary grindstone, and for such cases the details of the apparatus are nearly the same as those already described for tool grinding. The wheels vary from narrow to broad edges agreeably to the character of the work upon which they are used, and from coarse to fine in their grinding quality, especially when several machines are employed, that the work may be transferred from one to another as its surfaces progress towards completion. The spindles also very generally carry an emery wheel at either end, differing in coarseness or else in width or form of edge, for the same reason, to economize space, and to increase the range of work to be accomplished on any one machine; and the wheels generally run externally to the frame of the latter, unprovided with the hood shown by fig. 27.

Emery wheels may be roughly grouped as follows:—(A.) Coarse and rather rough, made of emery crushed to pass through a mesh of from 18 to 24 to the inch, used for the first removal of the rough outside skin of iron castings and general rough grinding. (B.) Less coarse, made from emery from 24 to 40 mesh, for similar use upon lighter iron castings, forgings and upon brass. (C.) Emery 40 to 60, suitable to follow for wrought iron, malleable iron and for general purposes. (D.) Finer, 60 to 80, preferred for steel and case-hardened iron, also for tools. (E.) Finest, emery 90 to 120, for finishing and smoothest surfaces.

Whether the work be applied by hand or presented mechanically, the best and quickest results are obtained by its comparatively light pressure upon the wheel running at a high velocity; the latter is usually driven at the rate of from 4,000 to 5,000 surface feet per minute, hence it is essential that the entire apparatus should be of substantial strength the wheel carefully mounted, in the manner already described, and perfectly true or circular; and for the last particular, rather frequent turning with the carbonate diamond tool becomes a necessity with all wheels in constant use. The surface works now under consideration are generally ground

dry, and being unhardened, the heat evolved when much material has to be removed is of little importance except from its inconvenience, and this may be reduced from time to time by dipping the work in water; on the other hand in most of the machines in which the work is mounted and traversed upon slides, a small jet of water is constantly directed on the surface under abrasion, or the work when beneath the wheel travels in a trough filled with water. Some of the machines used for dry grinding are provided with revolving fans to create a draught, to carry the fine metallic and other dust produced away from the operator. In bench machines, the fan of two or four blades is fixed midway on the spindle between the two wheels, surrounded by a jacket or casing communicating below, through a large horizontal bore in the base of the headstock, with casings placed around the lower halves of the wheels, the jacket opening behind into a pipe to carry off the dust. In machines mounted on iron stands, the fan is usually placed in the foot of the hollow pedestal and is driven by a pulley and strap.

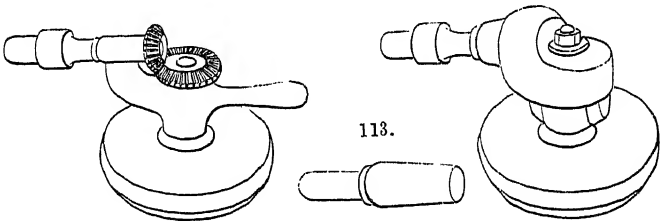
Hand grinding machines employed for long thin surface works, such as portions of stoves, are provided with flat, true, cast-iron tables, about twice as long as wide, placed above the wheels, hinged to supports above the frame at the back end and raised or lowered, to allow for the wear of the wheel, by an elevating screw at the other; and bear a close resemblance to the table of the saw machine, fig. 736, Vol. II., with the saw kerf replaced by an oblong aperture through which the periphery of the wheel slightly projects. The work when wide is laid flat on the table, held down under the outspread hands, and is traversed in all directions to and from the operator, and when the surface approaches completion, it is finished and the grain laid all in one direction by straight parallel strokes, as preparation for the polishing or burnishing. The guidance of the flat table is especially convenient for the long pliable narrow strips and beads used in stove decoration; upon these the straight strokes are alone used, and the rounded surfaces of beads are worked and cleaned by partially twisting the bar in the hands between every such traverse.

An apparatus for smoothing surface works, which employs the flat side of the emery wheel, is shown in two forms, figs.

111, 112. In both the emery wheel revolves within the rim of a round iron plate on the end of a short vertical spindle, running in collars in a tube cast on the plate; the spindle is surmounted by a bevil wheel, fig. 111, driven by a pinion carried by an arm, which latter also serves as one handle, the second handle cast opposite to it being straight. The other form, fig. 112, differs only in having the wheels and spindles mounted within a strong cast-iron covering. The workman presses the revolving wheel down upon the work with both hands, moving it about in small circles and traversing it in all directions upon it.

The free traverse of the apparatus to all positions on the work without interference with the continued revolution of the

Figs. 111. 112.

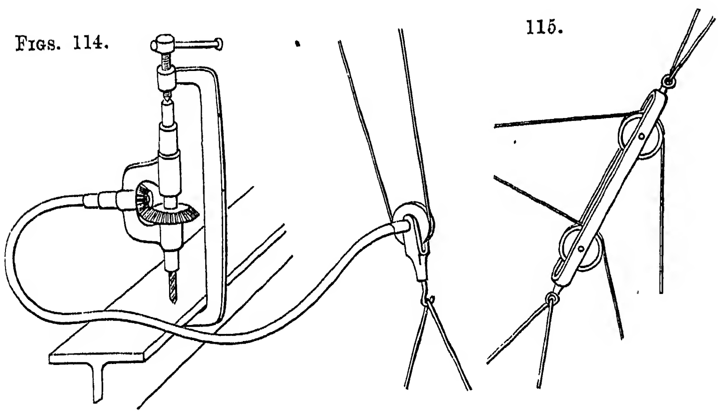


113.

wheel, is a notable feature of this simple grinding machine, and the ingenious "Stowe flexible shaft," by which it is driven merits description. The shaft proper, called the core, consists of four or five close spiral coils of round steel wire, wound hard upon one another, every layer twisting in the opposite direction to that upon which it is coiled; and an inch or two at each end of this snake-like structure is brazed solid and turned true for its attachments. The cores are from 3 to 8 feet in length and from a quarter of an inch to an inch and a half in external diameter respectively; in all the size of the single wires forming the coils gradually diminishes from the outer to the central layers, that of the external coil of the shortest core being about one-sixteenth, and that of the largest core about a quarter of an inch in diameter. The cores are contained and revolve within a moderately loose fitting cover, formed of a close spiral of flattened wire covered with leather, attached to collars at the ends. The solid brazed ends of the core revolve in and project through these collars,

the one to receive the fittings for and drive the grinders and other revolving tools, boring tools for wood and metal, or press drills for boring boiler plates, girders, &c., of the character shown in fig. 114, which are set in motion by a pair of bevil wheels in the same manner as the grinders and polishers fig. 111; and the other end to form the axis of the pulley which receives the power from a belt or cord, passing direct from a shaft above as in fig. 114, or led over a pair of stretching pulleys in a frame, fig. 115, which may be strained in any direction to allow the band to run free of neighbouring impediments. The driving pulley on the end of the flexible shaft

Figs. 114.



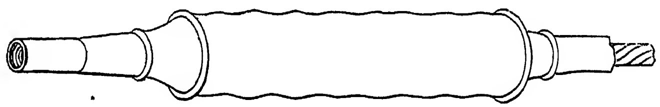
115.

is sometimes permanently mounted at the side or end of the work bench, and the general mobility given by these different arrangements, together with its own capacity of revolution when bent or curved in any required manner, enables power to be readily applied by the Stowe shaft to drive tools in positions otherwise inaccessible. In use the shaft revolves continuously and the tool is set in motion or brought to rest by means of a clutch contained within the tubular casing which connects the end of the shaft to the tool. In the grinders, figs. 111, 112, the casing is always grasped, being within one handle; turning this round one quarter engages the clutch, and turning it back again, the clutch is released and the grinder ceases to revolve.

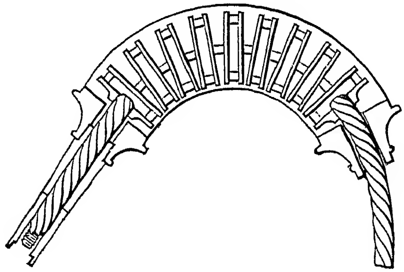
The smallest of these shafts are extensively used in dentistry for grinding and drilling both in artificial teeth and in those of

the living subject, and with great convenience in the latter case as the drilling or excavating tool can be exactly directed as a rod without interference from and distant from its driving power, a wheel and treadle. The writer has also made fluting drills and rose bits to a chuck fitted to a small Stowe shaft for carving and perforating in wood and metal, with good results. When used upon wood the chuck and encased end of the shaft are held somewhat like a pen, and the drill is employed for *bosting*, or the first removal of the material about the form, to be subsequently completed with carving tools; and in wood, ivory, silver and other metals, the drills thus driven may be employed for tracing and cutting straight and curved lines, grooving and sinking for quasi-chased work and for reticulated and perforated ornamentation. Small Stowe shafts are also used for driving appliances for sheep shearing, for grooming horses and numerous other purposes.

FIGS. 116.

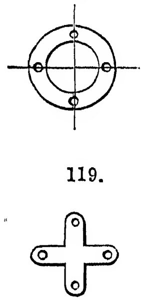


117.



118.

119.



The flexibility already possessed by these shafts has been considerably increased by the interposition of short but still more pliant couplings, patented by Mr. Arthur W. Browne, New York, 1885, which allow the original shaft to bend in much smaller curvatures than before without interference with its freedom of revolution. These short lengths consist of numerous thin steel plates in the shape of rings, fig. 118, or crosses, fig. 119, attached together in pairs by two rivets placed

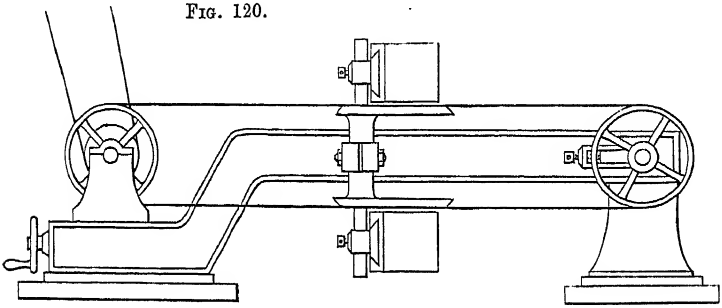
in one line, and each such pair attached to its neighbours in a similar manner but with these second two rivets in a line at right angles to the former, fig. 117; the two end plates are thicker and are braised to the ends of the twisted wire shaft, and the whole coupling is covered by a loose wire and leather casing of the same character and connected to that which covers the shaft itself. The Stowe shaft is cut to receive one or more of these couplings, or two ordinary lengths are joined by them; in figs. 116, 117, which show the coupling and its cover when straight and when bent, it is added close to the tool socket in which position it is employed with the grinders lately described.

In a machine much used for common works, a leather or thick woven canvas endless band from two to five inches wide, charged on the surface like emery cloth and fed in use with emery and oil, is stretched to run around a large driving pulley and two or four smaller guide pulleys, all with rims to prevent its displacement, and the spindle of one of the guide pulleys is adjustable to give it a moderate tension; the several spindles are also usually provided with similar pulleys at both ends to carry two grinding bands upon the same frame. The particular form of the latter is unimportant, but two are described in the catalogue under the head of WHEELS, article 62; the bands usually run externally to the frame of the machine, and the portion used may either run vertically or horizontally. The yielding surface of the grinding band usually has no guidance save that of the form to which the work has itself been cast, and such machines are only employed for cleaning and finishing the curved surfaces of small brass castings which are held down and twisted round upon the band in the fingers.

The horizontal run of the band is used in a machine, fig. 120, patented by Mr. Sugden, 1889, which machine is also provided with tables to support the bands and guides for grinding and cleaning flat faces square or at angles to one another. The horizontal frame has two band wheels at either end, two are mounted on the driving spindle which is carried by a moveable headstock with a screw and slide for tension, and the corresponding wheels at the other end are mounted independently to be separately adjustable to accommodate any small differ-

ence in the lengths of the two endless grinding bands. These latter run on the surfaces of flat rectangular tables with rounded edges, fixed above and below the frame at about the center of its length, and vertical rods through both pairs of tables carry the rests for the work. Some of the guide rests have plain vertical faces at right angles to the tables, and in others this face is provided with a transverse slide in the form of a vertical right-angled piece used for rectilinear work.

Fig. 120.



Various additions are made to the moving portion of the work rest to accommodate particular work; among them a clamp and screw, fig. 203, to press thin pieces on the band, and also a circular movement with a flat radial plate and clamp, fig. 204, which may be fixed to support works to grind their edges at any required angle to their surfaces. Joints in the bands are a serious difficulty, especially when the band runs across a table as they then give the work a more decided jar or jump every time they pass; with leather bands this is diminished but not altogether avoided by joining their ends as lap joints, both overlapping ends first carefully tapered away upon their surfaces before they are cemented together, so that the joint is as nearly as possible of the same thickness as the band. The endless canvas bands are woven without joint, and although, perhaps, less durable, are generally preferred.

Beside the question of accuracy the degree of smooth finish required for metal surfaces is relative, for that which suffices for most large works is generally inadequate for the smaller. The emery wheels hitherto and most of those yet to be referred to, are used for grinding the surface level, and to

forward it many degrees towards its ultimate finished condition, and although finer grained emery wheels used subsequently produce a sufficiently smooth surface in many cases, it is usually preferred to obtain the final surface by some of the other methods mentioned in this volume. In the emery wheels used as polishers or glazers, which are mostly of moderate size, *see* EMERY, article 12, the emery is not only considerably finer than in those used for grinding, but various other non-abrasive materials are introduced to slightly agglutinate in use, so as still to remain around the particles of emery and impede their activity, for just the same reasons that the cutler dresses the edges of his glazing wheels with wax. With the latter the thin dressing of wax and emery forced into the soft edges of the wheels soon wears out of shape and requires frequent renewing, but as the emery wheel glazers and polishers are of the same consistence throughout their substance, they may be used until worn down too small for service, and their edges are only reduced true by occasional turning to shape should they become deteriorated. But there is a different kind of glazing, which perhaps may be more correctly termed clogging, which sometimes interferes with the action of the ordinary grinding emery wheels. The conglomerate formed of the cement, lime and other materials, is necessarily less hard than the sharp particles of emery contained throughout it, that these may be left exposed to do their work by the more rapid wearing away of their stone envelope; but the heat which may be set up in the work by undue pressure and too heavy continued grinding, will sometimes melt both the particles removed from the wheel and from the work, and these then combine and adhere to the face of the wheel, first filling the minute interstices between the emery and then if the process be continued, forming a smooth coating which effectually impedes the grinding. Clogging or glazing of this character only results from unfair usage, and may be entirely avoided; in its earlier stages it may be removed by ragging or straggling with a thin iron scraper, *see* WHEELS, article 16, or even by grinding for a short time some other metal than that by which the mischief has been occasioned, copper being said to be the best for this purpose; but when it has gone too far, the edge of the emery wheel has

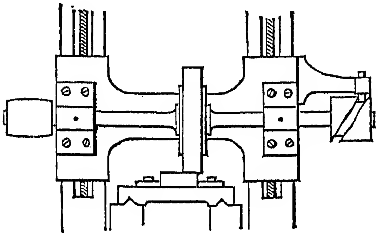
to be turned with a diamond tool to re-instate it in working condition.

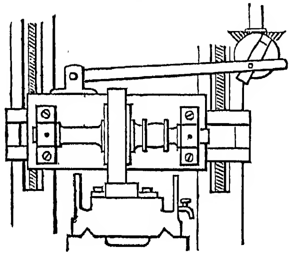
The surface emery grinding machines in which the work is presented to the wheel clamped down upon slides, differ rather considerably in construction but not in their general action. The hand machines for small and moderate sized works are usually mounted upon a cast iron rectangular pedestal, on the top of which there are two slides at right angles, the longer traversed by a chain or rack and pinion and winch handle, and the shorter one above it by a screw, intermittently, to traverse the work across as to its width under that of the wheel; and the upper slide carries a table or top plate with clamps and jaws to grasp the work. A rather coarse wheel of about six inches diameter is employed, fixed on the end of a horizontal spindle with a driving pulley, as on the mandrel of a lathe, standing above the table at right angles to the line of motion of the long slide; the spindle runs in bearings in a block mounted to move up and down on a strong vertical slide at the back of the pedestal, and the slide is provided with a screw turned by hand, to bring the wheel *down* in contact with the work.

In others for heavier works, the lower part of the upright face of the pedestal forms a vertical slide, which carries and raises a second and long horizontal slide, the face of which is also vertical; this second slide is provided with a main screw by which it traverses a heavy bracket, and the horizontal surface of this bracket forms a third slide at right angles to the second by which it is carried and traversed. The top plate of this third or cross slide is moved by a screw to shift the work clamped upon it under the width of the wheel. The grinding wheel of about twelve inches diameter and from two to three inches thick is placed above, mounted on a spindle parallel with the top slide which carries the work and in the direction of its motion. The spindle runs in bearings on the top of the pedestal, sometimes with the wheel on its free end, but for additional stability this end of the spindle more often runs on a center, carried by a strong arched-shaped piece above, forming a portion of the headstock. The driving pulley is placed between the bearings, and the rear end of the spindle is provided with a coarse screw and worm wheel, or some

analogous arrangement, to actuate a link and reversing ratchet to give continuous feed to the screw of the second or long slide of the machine, which connecting gear can be placed out of action and the slide moved by hand when first adjusting the position of the work. The feed of the top or cross slide is usually given by hand after every traverse of the work under the wheel, and the second slide is raised upon the first by a vertical screw, also turned by hand, to bring the work *up* into contact with the wheel.

Figs. 121. 122.



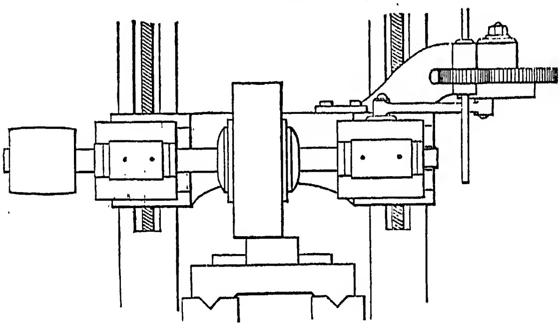


Other varieties of machines for larger and longer works, almost precisely copy the form of an ordinary planing machine with its self-acting motions for the table and cross slide, upon which latter the tool is replaced by the revolving emery wheel. In all of these the work reciprocates without lateral motion; in some the revolving emery wheel is intermittently shifted across the width of the work, but as often the wheel is continuously traversed to and fro across the width of the travelling work throughout the grinding, both to obtain a truer surface and to preserve the edge of the wheel itself in condition. The wheel spindle is sometimes reciprocated in its bearings by means of a swash wheel or cylinder, fig. 121, placed on its free end or between the frame and its driving pulley, actuated by a finger attached to and descending with the slide which carries the spindle.

In the method indicated by fig. 122, flanges on the wheel spindle run between bearings in a carriage, and the latter is reciprocated on the cross slide by a link and eccentric driven by a pair of bevel wheels, attached above to one upright of the frame; the adjustment of the eccentric permits the wheel any extent of traverse up to about six inches. A more compact

arrangement is employed in a machine, fig. 123, patented by Mr. E. R. Hyde, Springfield, Massachusetts, U.S.A, 1889. In this machine the traverse of the wheel carriage on the cross slide is given by a link, an adjustable horizontal eccentric and a spur wheel attached thereto driven by a pinion, all of which parts are carried by an arm on the cross slide; the pinion is turned by a vertical rod on which it is free to descend by a groove and feather, and the rod is driven by a worm wheel and screw at its upper end in a bracket fixed to the frame of the machine. In all, the cross slide receives a small inter-

Fig. 123.



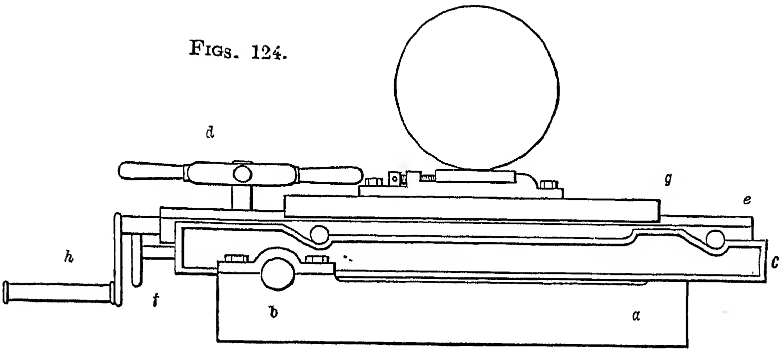
mittent descent to bring the wheel *down* on the work as the grinding proceeds.

The table is usually surrounded by a rim to form a tray to catch and conduct away through pipes the water used during the grinding. Sometimes, as in fig. 122, a high rim forms a deep well to retain sufficient water falling from the wheel to just cover the surface of the work to keep it cool, and excess flows away through a conduit pipe regulated by a tap.

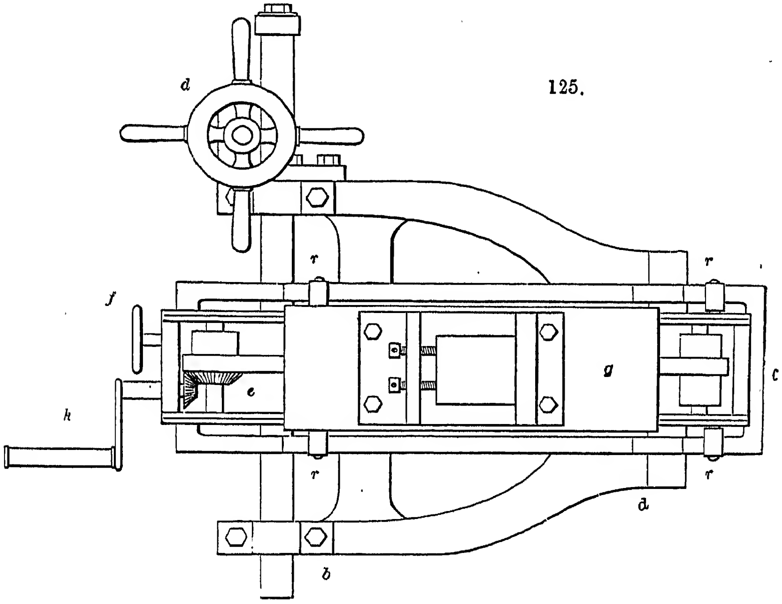
Besides the foregoing general types, many machines are especially constructed to meet particular requirements; and figs. 124, 125, indicate the moving parts of an emery grinding machine contrived and used by Mr. Chubb for surfacing the straight and diagonal bolts for the doors of patent safes and strong rooms. The base is a strong cast iron fork-shaped frame, *a*, which has a narrow true plane upper surface at its rear end, and carries a stout cylindrical rod, *b*, passing freely through fittings towards the extremities of its arms; and this

base piece supported or hinged within the stand of the machine by its rear end, is raised or lowered for the first approximate adjustment for the thickness of the work by a vertical screw,

Figs. 124.



125.



not shown, placed under a cross piece which connects its two arms in one solid. A rectangular frame, *c*, rests on the surface at the rear end of the fork, and is supported and held towards its opposite extremity by the rod, *b*, which is immovably fixed to it; and a rack with vertical teeth at one end of *b*, actuated by a hand wheel and pinion, *d*, serves to move the frame, *c*,

and all it carries transversely across the forked base. Upon *c* stands a second rectangular frame, *e*, with a solid bottom, supported upon it by four steel rollers, *r*, *r*, *r*, *r*, at the sides, which are received in corresponding hollows merging into inclined planes formed in the flat edges of the side rims of the frame, *c*; and this second frame held back and down by a strong spiral spring, not seen, is drawn in the opposite direction and up these inclines to give the final adjustment for depth of grinding by a screw, the wheel handle of which, *f*, is at the left of the figure. The top plate, *g*, which carries the work, moves as a slide upon the chamfered edges of the frame, *e*, upon which it is rapidly propelled to and fro by a flat chain passing around pin or cogged drums fixed within *e*, one of which is set in motion by a pair of large toothed bevel wheels and the winch handle, *h*. The emery wheel of coarse grain, twelve inches diameter by one and a half inches thick, with its spindle and driving pulley, runs in bearings in the upper part of the frame of the machine.

The steel bolts are square and rhombic shaped pieces, three quarters of an inch thick, from three to four inches wide by three and a half to six inches long, and are cut off cold from the rolled bar by a strong circular saw. To grind their surfaces one trial piece is clamped in the vice on *g*, and the machine is raised by the vertical screw below, before mentioned, to give the work light contact with the wheel; the work is then traversed lengthwise by the slide, *e*, and shifted laterally as to the wheel by the handle, *d*, between every such traverse. Should the flat surface thus ground show any residue of the skin of the metal, the work is then raised by moving the frame, *e*, a little way up the inclines on which it rests, and the grinding repeated. The machine then remains as adjusted, and the bolts are severally ground true on the one surface, each by three lateral shifts of position, and by passing once to and fro under the wheel with every such change to complete their whole breadth; the machine is then readjusted to gage for thickness, and the opposite surfaces of the bolts are ground true and parallel with the first after the same manner. Several bolts are lastly clamped together face to face to grind the edges true and square to their surfaces; and the grinding throughout is dry. The economy of time and material over

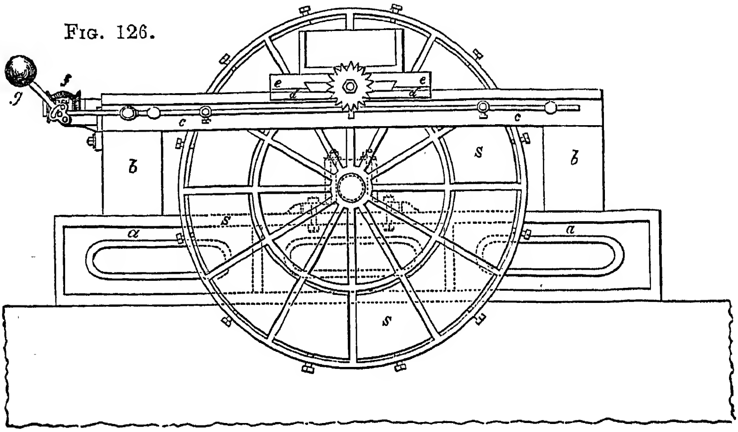
planing or filing is remarkable, for including fixing and releasing the bolt, every surface is completed in less than one minute, and as this accurate grinding permits the production of a surface by the simple removal of the thin hard skin of the metal, much thinner bars are used than would be otherwise possible. It should be also noticed in this convenient machine that all the moving handles are placed close together, so that the operator has to make no change in his position for their management.

A machine of similar character, patented by Mr. D. Ashton, 1888, is employed for grinding the forgings of blanks for files and other pieces of long and moderate surface curvatures. The grinding wheel mounted on a slide is lowered along the faces of the uprights of the machine by a screw turned by hand, to give the pressure on the work fixed on a travelling table below. The surface of the table extends beyond its frame, and flat plates or templates, straight above with their lower edges counterparts of the long curvature to which the blank is to be ground, are fixed to the sides of the table in contact with the under surfaces of its top projecting edges; and the table runs by the curved edges of these templates on two rollers, their axes immediately under that of the grinding wheel. The supports of the rollers stand upon stiff springs which, when the grinding wheel is in contact with the work, press the rollers and the table upwards, but also yield when the higher part of the curve is beneath the wheel. A long square threaded screw is fixed to the end of the table, and the two are traversed by means of a pair of bevel wheels, one cut with a thread for the screw to travel through it, and its fellow on a shaft with the driving pulleys; the mounting of the wheel on the screw having a small power of movement as a joint, to accommodate the slight undulatory movement of the table as it follows the curve. The grinding wheel has reciprocation in respect of its width, produced in the manner shown by fig. 121, and stops on the table work the reversing action of the driving pulleys as in an ordinary planing machine.

Some large surface works which require to be tolerably level and smooth for appearance sake alone, are ground traversed upon slides across the flat sides of ordinary large grindstones; but beyond the imperfect results, this method is objectionable

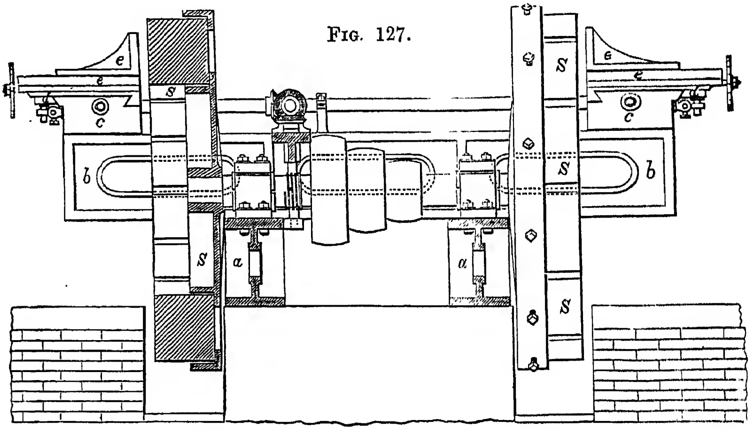
from the rapid wearing away of the side of the stone, which soon degenerates into an irregular obtuse cone. In a grinding machine contrived and used by the late Mr. James Nasmyth and shown in figs. 126, and 127, this difficulty was removed

FIG. 126.



by making the grindstone as an annulus about fifteen inches wide, composed of twelve sectors of stone each fitted into a separate radial compartment in a cast iron wheel or chuck

FIG. 127.



about seven feet diameter. The machine is double or possesses two compound grinding stones fixed on the opposite ends of the same shaft, each of the grindstones is provided with

separate slides which are duplicates of each other, and made self-acting. The foundation of the machine is of masonry, and pits are sunk on each side for the lower part of the stones to work in, just the same as for ordinary large grindstones. To the masonry are firmly fixed two cast iron frames, *a*, *a*, upon which are bolted two plummer blocks for carrying the main shaft, having at each extremity the large wheels or chucks, each made as a face plate seven feet diameter, having on the one side twelve radial ribs about six inches deep, that extend from the center to the periphery where they terminate in a ring of equal depth. A second concentric ring about four feet diameter intersects the ribs, and thus divides the entire chuck into twenty-four compartments, in the twelve outer of which separate pieces of grindstone, *s*, *s*, about fourteen inches thick are fitted like the stones of an arch, and each is wedged fast between the ribs by a single set screw passing through the outer rim of the chuck. On the top of the cross frames *a*, are fixed two longitudinal frames, *b*, *b*, for supporting the bearers, *c*, *c*, upon which the slides, *d*, are traversed across the faces of the stones. Upon the slides, *d*, are mounted at right angles the slides, *e*, upon which the work is fixed and advanced towards the stone as the grinding proceeds.

A self-acting motion is given to the slide, *d*, by which the work being faced is gradually traversed along the bearers, *c*, so as to bring the face of the work in contact with the revolving grindstones. This motion is obtained as follows. Upon the main shaft of the machine is fixed an endless screw, which drives a worm wheel fixed on an upright spindle, communicating by two pairs of bevel wheels and a short horizontal spindle, with a second horizontal spindle running the whole length of the machine, and having at each extremity a small bevel wheel that leads alternately into two other bevel wheels fitted loosely on the screw of the slide, *d*, which is traversed in opposite directions, accordingly as the one or other wheel is engaged by a central clutch seen at *f*. The clutch is shifted for every traverse of the slide, *d*, by means of a rod sliding endlong through two bearings fixed on the front of the bearers, *c*; and upon this rod two pins are fitted that admit of being adjusted to any distance from each other, according to the length of traverse required for the work in hand. A pin fixed

on the slide, *d*, is brought by the traverse of the machine in contact with one of the pins on the rod, and slides it endlong, so as to disengage the clutch from the one bevel wheel on the screw of the slide, *d*, and cause it to take into the other and reverse the motion; a counterpoise weight *g* is fixed on the rod to retain it steady while the clutch is being shifted. The upper slide, *e*, is also provided with a screw for advancing the work towards the stone in steps, as each layer is ground off by the traverse motion.

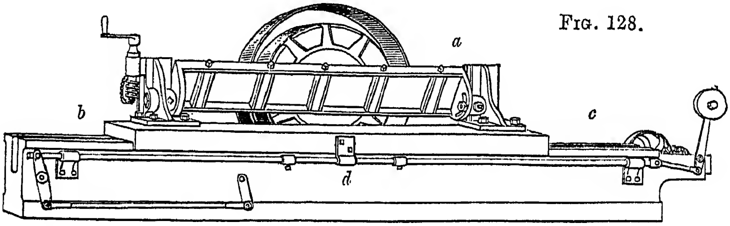


Fig. 128.

A machine on the same principle, but with some additional powers, shown by fig. 128, was patented in 1883 by Mr. H. Slack. The work is clamped down by jaws and side screws to the flat face of a long ribbed girder, *a*, which is pivotted to blocks carried in slides on the faces of two upright brackets at either end of a long horizontal slide, *b*. The girder, *a*, may be raised or depressed on the brackets, and also placed with its face vertical or at an angle by means of a worm wheel and tangent screw at the end, *b*, after which it is fixed down on the brackets, and the work may be held near to or away from its horizontal margins, adjustments convenient for choice of position in surfacing and for grinding flat bevels on the edge of the work, as for chamfered slide bars. The traverse of the slide, *b*, on the bearers, *c*, beneath it, is driven and reversed automatically, the latter effected by a tail piece, *d*, fixed to the slide, *b*, arriving in contact with two adjustable stops clamped at any required distance upon a rod which runs the whole length of *c*; contact with either stop by the traverse of the slide pulls the rod in the one or the other direction, which by a link motion actuates the reversing gear, and the slide travels back again. The annular grinding wheel of about two feet diameter is formed of twelve sectors of ordinary gritstone, about five inches and two inches at their wider and narrower

ends, and about four inches measured from one to the other, similar emery segments being sometimes employed, carried in the cells of a ribbed cast iron chuck similar to that lately described; the chuck is about six inches in depth, and the stones which project through it both on the front and rear faces to allow for their advancement when worn, are each secured by two binding screws with square heads for a key, tapped through its periphery.

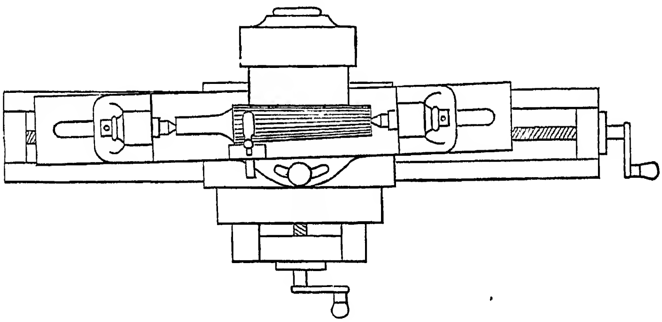
The chuck is carried on the end of a mandrel provided with a stepped driving pulley running in a large headstock like that of an ordinary lathe; and the headstock is capable of two movements upon a short slide upon its bearers beneath, which bearers are independent of the rest of the machine and are fixed at right angles to it and the traverse of the work. The slide and headstock are withdrawn along their bearers by a screw turned by a capstan or spoked handle to the distance required by the thickness of the work, and are then advanced by the same means during the progress of the grinding; secondly, the headstock is pivotted at the front of the slide and provided with a curved rack and tangent screw at its back end, by which the mandrel may be placed a little out of the right angle with respect to the work when it is desired to effect the grinding, not by the entire end surfaces of the stones as when it stands square, but by one side of their circuit or "track," to cause the stones to act only towards the outer edge of the width of one side of the revolving annulus.

The grinding wheel is driven at the rate of a thousand to twelve hundred periphery surface feet per minute, and a jet of water is directed on that part of its face which is in contact with the work, the water thrown off being caught by a sheet-iron guard mounted at a little distance around the chuck, whence it falls into a trough to conduct it away. The horizontal swivel movement in either direction given to the headstock permits the bulk of the grinding to be done with the entire surface of the annulus, after which a less active abrasion for the finishing is obtained by placing the mandrel at a small angle, as described, and the outer edges of the stones become more or less rounded by use from this last position, but within moderate limits from their surface wear in the first. Fig. 128 is employed for grinding the surfaces and edges of steel and

wrought and cast iron slide bars up to about eight feet in length, and for the flat sides and cutting bevels in the manufacture of long paper cutting machine knives, &c.; and subsequently to grinding the surfaces, several bars placed one on another are clamped down on the slide to grind the edges of all in the pile square to their surfaces at one operation. The girder and its supports may be removed so that heavy work may be fixed directly on the slide.

Analogous machines of smaller dimensions on the same general plan, but often widely differing in details of construction, have the built up wheel exchanged for deep annular emery wheels made as solid rings, which range from about

Fig. 129.



four to twenty inches in diameter, and from about one to four inches in width of annular face. These rings or crown wheels are mounted upon iron face plates, which are turned flat and recessed to leave deep rims to embrace their external diameters, and are carried on the end of a mandrel running in a headstock that can usually be shifted to place the annular face of the grinder either parallel with or at a small angle to the surface to be ground, the latter for the reasons already mentioned.

These smaller machines are in common use for grinding flat surfaces on metal, and the plan diagram, fig. 129, shows one employed for grinding the straight cutting edges of cylindrical and taper rimers and other fluted tools and cutters. The base of this machine carries two cross screw slides similar to those of a sliderest, the upper and longer at right angles to the axis of the crown grinding wheel, the lower advancing

the work into contact with its annular face. A long platform pivotted at its center upon the top plate of the upper slide carries different adjustable heads, some with center screws, between which the tools to be ground are mounted, and the platform may be fixed parallel with or at a horizontal angle to the transverse slide to agree with and maintain the original taper to which the teeth of the rimer or other tool are to be ground; circular cutters are mounted on an arbor, sometimes supported between the centers, and at others carried by a single head clamped on the platform. The tools are turned round from tooth to tooth by the hand, and an adjustable spring stop fixed on the opposite side to the grinding wheel on the platform, engages between two of their teeth and holds the tool stationary, as the edge of each tooth is carried past the grinder by the traverse of the cross slide.

An apparatus constructed and used in the writer's workshops for grinding the teeth of flat, single and double angular edged circular cutters, has some additional powers of adjustment. The square edged emery wheel, from about two to four inches diameter, runs on the end of the mandrel of a tall headstock that the work may be traversed across its edge and beneath it. Below and in front of the headstock there are two screw slides at right angles, the lower parallel with the mandrel, the top plate of the upper carrying a horizontal circular movement with a curved vertical arm somewhat after the construction of that of the spherical sliderest, fig. 594, Vol. V. A vertical circular movement at the upper end of the arm forms the pivot or trunnion of a piece bored at right angles to it to carry a rod upon which the cutters are placed whilst being ground, and so arranged that the axis of this rod is in the plane of the axes both of the upper and lower circular movements. The cutter rod or holder, therefore, may stand horizontally and parallel with the axis of the grinding wheel for square edged cutters, or at any horizontal or vertical angle to it for angular edged or skew teeth according to the angular positions at which the graduated circular movements may be fixed. In grinding, the cutters are traversed to and fro along the rod, and also along a straight edged guide piece which enters between two of the teeth opposite that being ground, shifted round from tooth to tooth by hand; the blade of the

guide is adjustable nearer or further from the rod to accommodate the diameter of the cutter, but its support being attached to the same piece that carries the rod, that and the guide are always parallel. Double angular cutters have the teeth ground first from the one face, and are then turned over on the rod to grind them from the other; the entire apparatus is raised by a vertical screw slide below its cross slides to bring the work into contact with the grinding wheel.

Similar machines are used in working horn, vulcanite, and mother of pearl, and differ principally as to the modes of holding the work, one example may be mentioned. The handles for dessert knives of the last-named material, taper on all sides from their butt ends to the blades, and they are also wider upon their sides than upon their edges. The blanks are sawn out of rectangular section and to the taper of their edges from the shell, and are usually then ground flat and to the taper of their sides, which come from the inside and the rough exterior of the shell, held in the hands upon ordinary grindstones, after which the blanks are rounded, carved and polished. When ground in emery machines, the rough sawn-out blank is held between the flat-edged jaws of a vertical holder, fig. 236, mounted on a slide-rest, gripped by its sawn edges between the upper jaw, which descends by a screw, and the lower jaw which moves on a pivot to accommodate its taper. The lower slide of the slide-rest, transverse to the axis of the grinding wheel, is moved by a rack and pinion to rapidly carry the blank across one annular side of the grinder, and the upper slide actuated by a screw advances the holder to place the blank in contact with it. In practice a number of blanks are first successively ground smooth and flat upon those sides which come from the rough exterior of the shell, after which they are regripped in the holder with these ground sides in contact with its vertical face, the holder being placed at a small angle in the direction of its traverse to give the taper, and advanced by the screw slide to a definite position towards the grinder to reduce the blanks on their second sides all to a uniform thickness.

CHAPTER V.

THE FIGURATION OF STONE AND MARBLE BY ABRASION.

SECTION I.—QUARRYING AND THE PREPARATION FOR PLANE SURFACES.

THE tools employed in the interesting processes of quarrying stone nearly all abrade or pulverize the material by percussion, and the oldest and simplest forms of these tools continue in general use, although many of them have received the addition of machinery to aid or to entirely replace the hand power, by which all were formerly guided and driven. In the softer stones, deep grooves or channels are cut with picks and chisels, and in the harder, deep holes are sunk at frequent intervals in lines along the material, for the insertion of iron and steel wedges or of blasting charges to detach the mass from its bed. Besides much labour, considerable judgment is required as to the position and number of these channels or holes, according to the hardness and stratification of the particular stone to be won and the surroundings of the mass in its bed, points which can only be determined by the practical skill and experience of the quarrymen. The purely abrasive process of boring holes through all stratifications with the diamond drill, *see* DIAMOND, article 6, does not appear to obtain to any extent in quarrying, although constantly employed for very deep wells and for making the holes in submarine rocks for blasting.

In quarrying the softer stones the holes are made with comparative ease with the "jumping bar," or by chisel ended rods, tools described later, driven with hammers and mallets; but mechanical drills are also used in adits and other places convenient for their fixing, these tools are made in various forms of which figs. 130, 131, are general types of those driven by hand. The drill is a flat bar tipped with steel, and twisted into a simple auger with two square cutting or grinding edges, with a square shank to fit into the socket of the boring bar;

the latter, a long rod cut as a square threaded screw from end to end, revolves in a long plain hole in a circular or rectangular box when turned by its winch handle. The box is carried on a single or upon a double standard, fig. 130, which may be placed vertically or otherwise, as may be convenient for its fixing, and is elongated by screws to force its terminal claws into the surrounding stone. The box may be placed anywhere

Fig. 130.

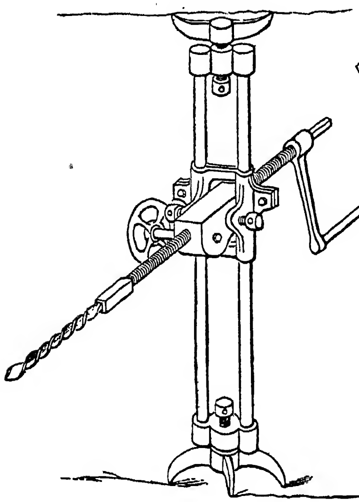
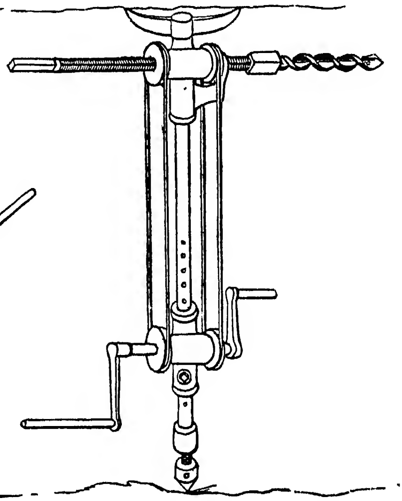


Fig. 131.



upon the length of the standard and at any angle to it, and the bar is advanced by a ratchet motion and a pinion working on the screw for its rack, contained within the box and turned by a key or handle from time to time as the drill penetrates. To overcome hard places sometimes encountered in the course of boring the holes, the socket end of the bar which receives the drill is made square externally, that hooked wrenches may be used upon it by men standing on either side. The second form, fig. 131, is employed to put holes within a few inches of the roof, sides or floor of the adit. In this the screwed boring bar is grooved throughout its length, and is turned by a feather in a wheel placed at one end of the plain hole in the transverse box, driven by a chain from a corresponding wheel with winch handle below; a second wheel revolving within a fork, one half of which is the other end of the box, and

screwed to fit on the bar, serves both to advance the drill and to withdraw it after it has completed its work, this is also driven from below. Similar drills of larger calibre driven by compressed air, hydraulic, or other power, are mounted on trolleys to run on rails laid down in the adit. In one of these, patented by Mr. T. H. Bell in 1888, the screwed rod carrying an auger, a copy of the form shown in figs. 130, 131, is rotated to advance or withdraw the drill from the one end of a long cylindrical structure, the other end of which carries a petroleum engine by which the screwed rod is put in revolution. The cylinder itself can stand horizontally or be pointed to any angle upwards or downwards on trunnions placed at the center of its length, which work in bearings on a strong cast iron frame, moved by a large worm wheel on one of the trunnions and an endless screw on the frame; and the latter can be placed and clamped higher or lower upon a massive iron post, which stands on the center of the platform of the trolley. This upright also rotates on its spreading base, which is formed as a worm wheel and is turned by an endless screw fixed on the trolley, so that the drill can be presented parallel with the length of the trolley, or at any angle to it. The attachment of the shank of the drill to the end of the screwed rod shown in figs. 130, 131, is replaced by a Hook's joint, a peculiarity which permits the drill to still rotate and advance should the varying hardness of the stone lead it more or less away from the strict axial line of the screwed rod. The hewn blocks first roughly squared with pick and chisel, are divided, worked into shape and finished or polished by the methods described in later pages.

The more compact and crystalline rocks, of which granite may be taken as a hard and practically unstratified example, require far greater labour and are somewhat differently treated. In the granite quarries at Penryn, Cornwall, worked by Messrs. Freeman and Sons, the general practice is as follows. The holes for blasting are driven both by hand and by percussive rock drills, both of which methods pulverize the material. By the former the larger blasting holes placed vertically, horizontally, or at angles as required, are made with heavy round iron bars of different lengths ending in hardened steel chisel edges spread out rather wider than their diameters.

For vertical holes of moderate depth the bar is held by one man, sitting, who lifts the bar and also twists it partially round, to present its chisel edge at a different angle, between every blow struck on its upper end with sledge hammers by one or two assistants. By changing the bars for others longer as they advance, vertical holes are constantly driven to a depth of twelve to fifteen feet in this manner, and sometimes to twenty feet. The iron bars employed for these deep holes are two inches in diameter with wide steel chisel edges, and they also carry a round collar at a short distance up the bar, of a diameter slightly less than the width of the chisel edge, which is found to assist in preventing the hole from becoming irregular, and to keep it fairly round and true. For horizontal holes, sometimes shallow, but frequently driven to a depth of fourteen feet, the bar is suspended by chains to tripod supports as a battering ram, and is turned partially round by one man between the blows struck on its end by others.

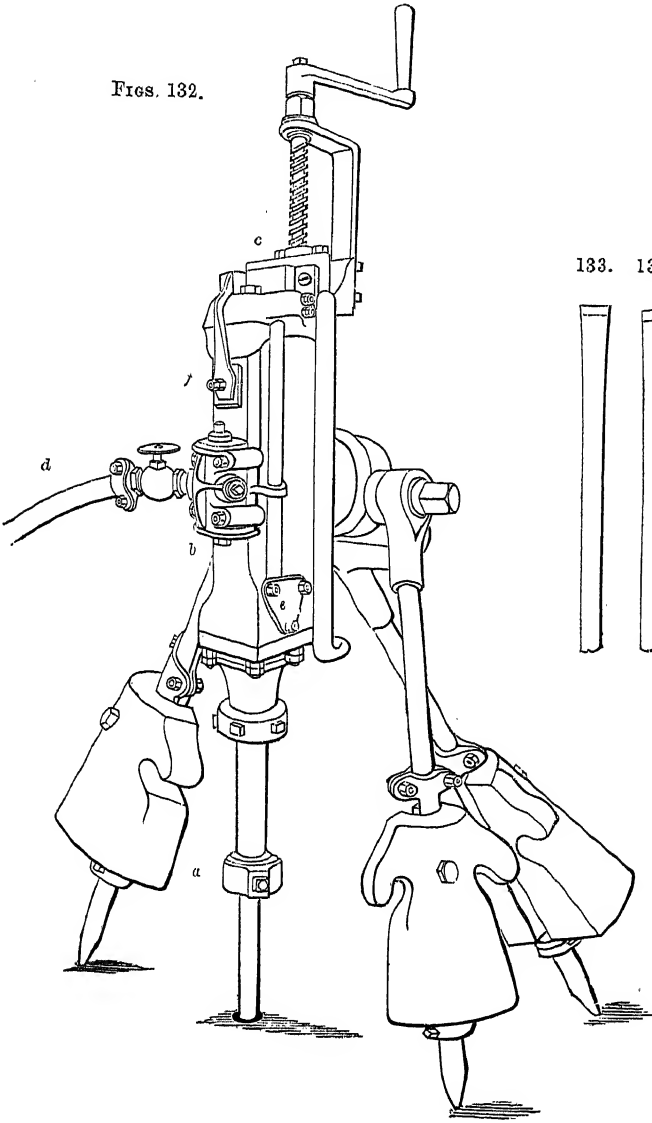
Vertical holes of less depths and diameters are made by one man only with the "jumping bar," a strong double ended iron bar from three to four feet long, with steel chisel edges and a heavy bulb in the centre of its length to give it weight. The workman sits astride the block, raises and then lets the bar fall through his hands continually on one spot, partially twisting it round every time in its rebound; and in jumping holes as also with the driving bars, the growing hole is plentifully supplied with water to collect and carry away the pulverized dust.

The percussive rock drills, driven by hand or power, carry boring bars which closely resemble the hand tools, already described, attached to the end of a reciprocating plunger mounted on a slide by which the bit is gradually advanced as the hole progresses, and at the same time receives a partial rotation between every blow; the plunger is actuated by steam or compressed air, the feed and revolution of the bit are sometimes given and regulated by hand, but both these motions are more generally made automatically.

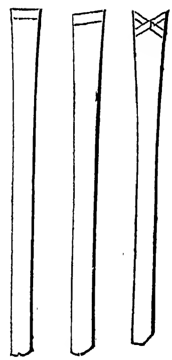
In the power machine, fig. 132, the boring bar is received in a socket with a binding screw, *a*, at the end of the piston rod of a cylinder, *b*, which latter is mounted to traverse along a strong slide, *c*. Three pointed legs jointed and moving upon

trunnions cast in the solid on the back of the slide, *c*, are provided with removable iron weights of about 70 lbs. each,

FIGS. 132.



133. 134. 135.



which, together with its own weight, give the tripod machine sufficient stability to withstand the impact of the blows produced by steam or air at about 50 lbs. pressure, conveyed

to the cylinder through the flexible pipe, *d*, notwithstanding the rather violent oscillations it acquires when at work. The cylinder of $2\frac{1}{2}$ inches diameter has its valves in front, and is constructed to leave a cushion of steam or air at each end, so that the piston never arrives in contact with the top or bottom; and the machine which is about five feet in height has a spread of about thirty inches from point to point of its legs. Fig. 132 strikes from 300 to 600 blows per minute, and makes very rapid progress, throughout which the hole in course of pulverization is continually supplied with water.

The boring bars have square or bevelled chisel edges, or two such edges in the form of a cross, fig. 135, the last used for granite, all taper from their edges to their round shafts to give some clearance, and are made of steel tempered to a deep straw colour. Those for machines with $2\frac{1}{2}$ inch cylinders, range from one to one and three quarters of an inch in width of edge, and by exchange of drills, each of which lengthens the hole something less than sixteen inches, the extent of the feed, fig. 132, may be employed to pulverize a round hole to a depth of about eight feet. Granite may be pierced at the rate of from five to six inches per minute; hence, at a low computation, the machine is capable of doing from ten to twelve times the amount of work that could be performed in similar times by the most expert hand labour. Porphyry has been bored with a one and a quarter inch hole at the rate of from 2 to $2\frac{1}{2}$ inches per minute. Machines with 3 inch cylinders work drills up to $2\frac{1}{4}$ inches width of edge, and may be used to bore to a depth of about twelve feet; and still larger machines carrying boring bars from three to five inches in width of edge, the writer is informed, have been used to bore to a depth of forty feet.

The tripod drill as in fig. 132, stands to bore vertically, but it may have its cylinder placed and used horizontally or at any angle, and in any position which affords solid support for its three feet. In another form, used for working within adits, the slide and cylinder are mounted, and can be placed to any vertical height or angle, upon a single strong wrought iron upright, which is fixed by claws at the top, with baulks of timber interposed, against the roof, by means of screw claws or by an hydraulic press attached to its lower end against the

floor. This arrangement is extended for working in larger galleries. The massive upright is then cut as a coarse square threaded screw, and with its hydraulic press below is carried on a trolley; one and sometimes two strong cross arms of round section stand at right angles on this vertical screw, mounted by plain holes pierced through large bosses at the center of their lengths; they are raised or lowered and clamped by large nuts upon the vertical screwed upright, and after adjustment, are further fixed to stand square or at any angle across against the sides of the gallery, either by screw claws or by small hydraulic presses attached to their extremities. The horizontal cross arms each carry two independent rock drills, which may be clamped to stand at any angle upon them and anywhere upon their length, or to work beyond the ends of the arms in the direction of their length. From this universal mobility, travelling multiplex rock drills are very successful in tunnelling and other large work, and they may be employed in adits down to those of about eight feet square; the drills are more generally driven by compressed air, every one usually in charge of a separate attendant.

The twist or partial rotation of the boring bar is always self-acting, but the advance of the cylinder along the slide for the tool to keep pace with the increasing depth of the hole is very often given by hand, and from the variable nature of the stone penetrated, this is liable to error. In fig. 132, both motions are effected automatically by an elegantly simple mechanism patented by Mr. Hawthorne, which also has most of its working parts boxed in under cover. The long piston of the machine is in one solid with its rod, which latter by the socket and binding screw at its lower end carries the boring bar; these portions, therefore, may be considered as one continuous piece. To give the twist, the upper end of the piston is hollow and rifled, or cut with a quick multiplex thread of about one quarter turn in eight inches, to receive a corresponding spiral steel rod having a short cylindrical portion at its upper end. This portion of the spiral rod passes through a plain hole in the solid top of the cylinder, above and upon the upper surface of which it carries a ratchet pinion securely fixed to it, and the pinion is provided with two opposing detents so that it can only turn in the one direction; the

pinion and detents are inlaid in the underside of a solid cover, which is secured and packed steam tight upon the true top of the cylinder. Every time, therefore, that the piston ascends the spiral rod, it moves that and the pinion through a small part of a rotation, at which new position they are held by the two detents, and the spiral rod thus held fast during the descent of the piston, twists that and the boring bar round a corresponding slight amount for every blow.

The automatic feed is effected as follows. A round rod outside and parallel with the cylinder, passes through a steam tight packing in the upper surface of a square box or port, *e*, opening into the lower end of the cylinder; and within this port the rod terminates in the solid in a short arm or lever at right angles, the bevelled extremity of which projects just within the cylinder. The rod secured in position by passing through an external bracket placed about midway as to its length, is carried at its upper end through a plain hole in the edge of the false cover of the cylinder previously mentioned, above and upon the upper surface of which latter, it terminates in a second lever which is hooked at its extremity and stands at right angles to the rod. The end of this finger engages in a corresponding hook formed in the shorter end of a paul, a right angled lever detent, pivotted on the top of the false cover of the cylinder; the longer arm of which third lever acts upon a pinion, which is free to revolve, but is held and prevented from any vertical movement between the faces of a bridge-shaped piece attached to the end of the slide which carries the cylinder. The pinion is tapped and works freely upon a long square threaded screw of three threads to the inch, seen in the woodcut, mounted in the framework which carries the slide, and it is provided with a second detent that it may turn in the one direction only during the feed; lastly, the longer arm of the paul is pressed against the pinion by a strong spring, *f*, which retains the whole system in action.

The bottom edge of the piston at every descent strikes against the bevelled end of the lower lever of the rod and pushes it out of its way into the port at the side, and the rod thus partially turned, then by its upper lever and the paul, partially rotates the pinion on the screw, and as the latter is standing still, this every time effects a corresponding and small

descent of the slide carrying the cylinder. The force of the blow being equal, the bit at every stroke enters the rock to a greater or less depth as that may be harder or softer, hence the piston descends only in corresponding degree, and in consequence, its lower edge passes more or less down the side bevelled end of the lower lever, and, therefore, moves and rotates the rod to a greater or less extent, and the pinion more or less round upon the screw; by this ingenious arrangement, the feed is throughout exactly and automatically adjusted to the extent of the possible depth that may be pulverized by every individual blow, according to the frequently varying conditions of the hardness of the particular rock upon which the machine may happen to be employed. With the feed detents placed out of action the screw is turned by its winch handle above, to advance the slide to place the bit in light contact with the rock prior to admitting the compressed air or steam; and the screw is turned in the reverse direction to wind the carriage up again when it has arrived at the end of its downward traverse, to withdraw the drill or to exchange that for a longer to continue the hole.

The percussive rock drills worked by hand power are mounted after the same manner as those just described. The piston is in the solid with a rod which passes through both ends of the cylinder, and the force of the blow is given by a strong spiral spring contained within the latter, which is compressed and released by cams acting on a cross head on the upper half of the rod. A spindle placed at right angles to and behind the slide carries two large discs keyed to it, each of which has four arc shaped ribs or cams cast upon its flat inner surface, equidistantly placed, and proceeding from its periphery over about two-thirds of the way towards its center. The spindle terminates in two moderately heavy fly-wheels of about two feet diameter with a winch handle in the rim of each. As the spindle is turned, the round ends of the cross head are drawn upwards by the convex edges of one rib on each disc and the spring compressed, until they arrive at and are released by passing over the terminations of the ribs, when the spring extends and gives the blow; the next pair of ribs immediately engage the cross head and again draw up the rod and so on, every revolution of the driving spindle, turned by a

man at each fly-wheel, giving four blows. In another form the discs are replaced by two S shaped arms mounted by their centers, the convex curvatures of which draw up and release the cross head, and give two blows for every revolution of the spindle. The lower end of the piston rod carrying the bit, acquires a partial rotation by means of levers and detents set in action by its reciprocating passage, and the advance of the slide with the cylinder is given by a screw turned by hand. Although laborious to work, and comparatively of moderate force, these hand machines pulverize holes in granite at the rate of from 1½ to 2 inches deep per minute, and there are many conditions under which they find profitable employment.

The masses of quarried granite are divided, roughly squared, and prepared for use in the following manner. A series of smaller holes about three inches deep and a few inches apart, are made by "jumping" or with rock drills all along the face and ends of the block upon the intended line of separation; these are then filled with *feathers*, two half round pieces of iron with steel wedges between them, and lastly the entire series of wedges are gradually and equally driven home until the stone splits, which it usually does with a fairly flat fracture. Any large irregularities are reduced after the same manner, after which the facing done at the quarry is carried one step further, where it usually terminates, with heavy chisel-edged hammers and steel picks. A smoother finish, however, is sometimes put on dressed blocks with a *bush axe*, a tool composed of five or six hardened steel plates from a sixteenth to one eighth of an inch thick, their edges ground to a double bevil, clamped side by side in an iron frame or matrix; the blows from the edges of this compound axe are all laid parallel on the stone. In France the bush axe is replaced by *bouchardes*, hammers of hardened steel varying in size from about 1½ to 2½ inches square in section, and from six to nine inches long respectively, with eighteen-inch wood handles placed centrally as to the length of the head. The square faces of these hammers are cut into very regular, four-sided, pyramidal teeth which vary in number from sixteen to some hundreds, the finer following the coarser in use, the height of these pyramids being always about one and a half times that of the width of their bases. The *boucharde* is used

on both the hard and soft stones. Subsequent accurate shaping, facing and polishing is carried out by sawing, with smaller hand picks and chisels, and by polishing rubbers, mentioned in the foregoing Catalogue, and by numerous machines to be described later which replace hand work. Among these machines a remarkable apparatus for quarrying will be described, which is deferred to follow the particulars of a machine for sawing stone from which it was derived.

SECTION II. THE PRODUCTION OF PLANE SURFACES IN STONE AND MARBLE BY HAND.

The softer varieties of stone such as Bath, Caen, and Penswick stones, admit of being cut into blocks, slabs and smaller pieces with toothed saws, which are usually made of a similar form to the cross cutting saws for wood with coarse upright teeth, shown in figs. 640 and 643, Vol. II., but the toothed saws for soft stone are generally made somewhat wider in the middle than those for wood, so as to make the blade more rounding in the direction of its length, and instead of being reciprocated backwards and forwards nearly in a horizontal line, as for cross cutting wood, the toothed saws for stone are used with a swinging stroke, so as to act upon only a moderate portion of the length of the cut at the one instant of time to reduce the labour and give the saw teeth more penetration. Some of these soft stones, of which a variety of Bath stone known as "Stoke ridge" is an example, are very readily carved and worked into form and mouldings with chisels and gouges similar to those of the carpenter, but the worked surfaces subsequently considerably harden from exposure to the atmosphere.

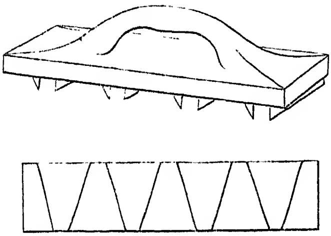
For a simple slope or bevel the block is first marked with lines across its ends and along its length, made with a piece of soft slate found among coal and called "black," and the material is chipped away in flakes nearly down to these lines with a mason's chisel, a steel tool about 6 to 8 inches long with a straight cutting edge from 1 to 2 inches wide ground to a bevel from both sides. The first rough surface is then equalized with a carpenter's firmer chisel, from 2 to 3 inches wide, in a wooden handle, under the guidance of a wood

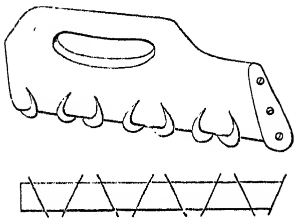
straight edge, both tools being presented to the surface with their shafts at an angle of 45°, gently struck with round leaden mallets of rather small size. The surface is then completed with a scraper, a piece of steel saw blade usually of semicircular form, its diametrical and working edge from 4 to 8 inches long and cut into teeth of the size and shape of those shown in the illustration, fig. 643, Vol. II. The scraper held by its round edge in the fingers of both hands is presented to the surface at the same angle as the chisels and its toothed edge is pushed forward diagonally across it; a series of these short strokes carried from one end of the bevel to the other, under the guidance of the wooden straight edge, is followed by a second carried the reverse way, and so on to the completion of a smooth surface with very rapid effect.

The same general process is followed for a rectilinear moulding of several members, such as that indicated by fig. 793, Vol. II. The ends of the block are marked with black to the section of the moulding desired, and just beyond the most prominent members with diagonal lines, the ends of which latter are connected by lines marked along the length of the block, which is then cut down to such bevel and made true. If large such a piece may be sawn off, but if small it is chipped and worked off in the manner lately described. Deep portions which have to be removed in working large mouldings, are then sawn out to guide lines made on the ends of the block and connected by others along the bevel, after the manner indicated by the lines in fig. 793, Vol. II.; but the saw is also very generally employed in the smaller mouldings, which might be entirely chipped and cut out, for the benefit of the guidance for subsequent operations afforded by the equal depth and straightness of the cuts made with it. The saws used for thus *bosting* out mouldings in the soft stones vary from 2 to about 5 feet in length, but the edge is straight, and all have transverse handles similar to those of a cross-cut saw and are worked by two men. The fillets and flat members are first wrought in the manner already described, except that the toothed scraper, while held as before, is also used traversed straight along in the line of its teeth to clear out and sharpen all internal angles. The positions of the beads and convex members are next marked on the flats, and these are then

chipped round with the chisels and finished with the scraper and carpenter's coarse rasps; concaves are cut out with round ended chisels, carpenter's gouges and rasps, all the tools being used under the frequent guidance of the straight edge.

Figs. 136. 137.





The French masons employ compound scrapers for completing the flat and concave members of mouldings in the softer stones. That for the former called "le chemin de fer plat," fig. 136, consists of a hardwood slab some nine or ten inches long by three inches wide, with a handle above and six or seven parallel slips of steel plate inserted diagonally in reversed order projecting about half an inch on its under face or sole; in some of these tools the steel slips have plain straight edges, in others they are cut into saw teeth, in which case the points on one plate are placed to stand opposite the intervals on its neighbours. The workman places the one hand above the other on the handle, and one of these tools serves for all widths of flats. The tool for concaves, fig. 137, called "le chemin de fer rond," is a single block of wood and is held by both hands after the manner of a plane; the round edged steel plates, a little wider than the wooden stock, are inserted in its rounded sole after the manner already described except the first, which covers and protects the front end of the tool; one or two of these tools of different widths are required, but as with the carpenter's round planes, any one will serve to work a larger concave than, as also one of its own width.

Slate as mentioned at page 165 of Vol. I. is sawn and sometimes planed with cutting tools very similar to those used for wood, except that they are stronger and are applied by machinery, the action being partly cutting and partly forcing off the flakes of slate, for if the tools are allowed merely to

scrape over the surface their edges become rapidly worn away. The various sandstones, limestones, marbles and granite are too compact to be thus treated, and they are consequently worked, if by hand, almost exclusively by the chipping chisel and various abrasive processes; the chisel being used for such parts of the material as are in excess, as in sculptured works, and the abrasive processes being employed for dividing the blocks into slabs and small pieces, which are subsequently ground to the required forms generally with sand and water. In the case of marble the pieces are finally polished with abrasive powders applied on rubbers of various materials and in the order mentioned in the Catalogue under the head of Marble.

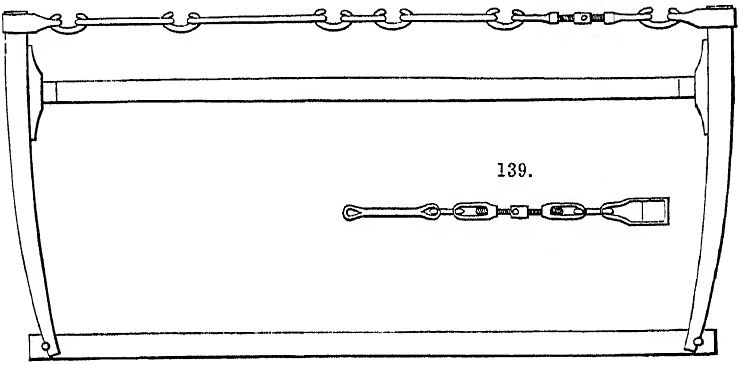
The ordinary saw used for dividing blocks of stone and marble into flat slabs, is shown in figure 138. It consists of a parallel blade of soft iron from 5 to 10 feet long, from 4 to 5 inches wide, and from one-eighth to one-sixth of an inch thick, the blade is perforated near each end with a hole about three-quarters of an inch diameter, for the reception of an iron pin by which the saw is strained in a rectangular wooden frame. The blade is inserted in the saw kerfs in the upright sides of the frame, called the *heads*, and the pins rest in two notches near the lower extremities of the heads, which serve as the handles of the saw, and are kept distended by the wooden stretcher called the *pole*, placed about a foot from the upper ends of the heads, and rested at each end against a loose block of wood called the *bolster*.

Instead of a coil of twisted string with a short lever being employed for drawing the upper ends of the frame together as in the saws for wood, this object is effected by the use of a kind of chain made of looped iron rods, with intermediate C-shaped links, for adjusting the total length of the chain, which latter terminates in iron loops that embrace the upper ends of the heads. The tension is given by a right and left hand screw fitted to two looped nuts, attached to the iron rods by C links, the double screw has holes for a lever, by which it is twisted so as to draw the upper ends of the heads of the frame together with great force, and thereby stretch the saw in a most effectual manner. The top view of the tightening apparatus is shown separately, fig. 139. The depth to which

the saw can penetrate is limited by the distance from the edge of the blade to the under side of the pole, the nearer the pole is to the saw the greater is the stability of the blade, and all the parts of the frame are made detached, so as to allow of their being combined and adjusted to suit the different sizes of blocks of stone. The same pair of heads are used with

Figs. 138.

139.



poles and saws of various lengths, and the pole is placed at different heights from the blade, according to the depths of the blocks of stone. When the latter are very deep, a longer pair of heads are substituted, but long heads are avoided as much as possible, as they considerably reduce the stability of the saw-frame.

The blade of the stone-saw, like the metal-laps used for grinding generally, does not itself cut the stone, but simply serves as the vehicle for the application of the sand, which acts as the teeth of the saw and performs the cutting process. The coarseness of the sand employed depends upon the hardness of the stone to be cut, for moderately soft stone a coarse sharp sand is used, and for the harder varieties of marble a fine sand; the sand or grit employed in London for cutting stone is sometimes obtained from the scrapings of roads paved with flint. The scrapings are sifted and washed through perforated copper sieves, much the same as emery, as it is of great importance that the sand should be clean and quite free from small pieces of stone or any other extraneous matters. Should a small piece of wood or a bit of coarse gravel by any

accident get into the kerf beneath the saw blade, the little piece would roll over backwards and forwards, and materially impede the cutting of the block, and it then becomes necessary to remove the saw and wash away the obstacle, by pouring water down the saw kerf. Copper saw-blades and emery are used for sawing granite, but the process is slow and laborious and is seldom effected by hand. In the machines for sawing granite, described in the next section, emery is often replaced by Mr. Tilghman's Iron Sand, an effective material described in the Catalogue under Granite, Article 2.

The cutting action of the sand is assisted by a small stream of water, supplied from a barrel placed a little above the block of stone. A small hole is made near the bottom of the barrel, to which is fitted a spigot and faucit, or more commonly a loose wooden peg grooved up the one side, which allows of the escape of a minute stream of water, that trickles down a sloping board placed so as to lead the water into the saw kerf. A little heap of sand is placed near the path of the water, and the workman is provided with a wooden stick with an iron hook at the end, or more commonly an old knife blade placed at right angles to the stick near its end. This tool is called a *drip stick,* and is used occasionally to draw forward a small quantity of sand into the running water, which thus carries down the necessary supply for the cut, and the water flows away at the end of the kerf, carrying with it the worn-out sand and the particles of stone removed in the cutting; the drip stick is also used for tapping the wooden peg, so as to increase or diminish the flow of water according to circumstances.

The weight of the saw and frame supplies the necessary pressure for causing the penetration of the sand, so that the workman has only to guide the saw, and push it backwards and forwards for the cut, but when the saw-frame is so large that its weight renders the work too laborious, a lump of stone or iron is hung to it as a counterpoise by a rope led over a pulley overhead, and with the pressure thus modified, the saw works more easily but cuts less rapidly.

To mark the block of stone or marble with the lines upon which it is to be sawn, as for cutting it into slabs of one or two inches thickness, the block is first shifted upon rollers into place beneath the saw; it is then mounted upon square pieces

of wood called *skids*, with that side of the block upwards which is to constitute the edges of the desired slabs, and as the blocks are frequently of very irregular forms, it is necessary to make one line around the top and the two ends of the block, to serve as the basis from which the other lines are set off, much the same as in setting out round timber described in pages 703 to 707 of Vol. II. The position of the first line having been determined, so as to allow of the greatest number of parallel slabs being cut from the block, two marks are made on the top of the stone close to the ends with *black*, a line is then drawn under the guidance of a straight edge to connect these two marks and the line is continued down one end, also with a straight edge. An equal distance is then set off at the bottom of the opposite end, and a line is drawn to serve as a temporary guide; two straight edges, each from two to three feet longer than the depth of the block, are applied to the two end lines, and the workman looks along the line of the two straight edges, to see whether they are parallel with each other, or out of winding, in much the same manner as in the application of the winding sticks to narrow works in wood, explained at page 500 of Vol. II., except that for setting out the blocks of stone, the straight edges are placed perpendicular instead of horizontal. Should the straight edges not appear to be parallel, the one at the second end of the stone is shifted at the bottom until the two are in one plane; the permanent line at the second end of the block is then drawn in the corrected position of the straight edge, and if the work have been correctly performed, all the three lines will be in the same plane. The thicknesses of the required slabs are then gaged off from this foundation line, and the lines on the top of the stone are *chased*, or cut in about one-eighth of an inch deep with a narrow chisel, to form a groove in which the edge of the saw is placed for the commencement of the cut. The end lines are also chased, as the water and sand would wash out the black lines.

Before commencing the sawing, the workman examines with a plumb line whether the end lines are vertical, and if not, wedges are driven under one side of the block to bring the end lines exactly upright, the saw is then placed on the groove, and the sawing is proceeded with, care being taken in the

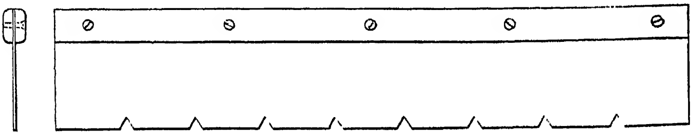
first entry to keep the saw quite upright, which is greatly assisted by the height of the saw frame. Should the saw make the cut a little oblique to the lines, the position of the blade is slightly twisted in the saw kerfs of the wooden heads, by blows of a hammer applied on one side of the pins which retain the blade in the frame, which causes the saw to cut in the reverse direction. The necessity for changing the direction of the cut is, however, avoided as much as possible, as it makes the surface of the slabs irregular from the hollows thus produced, which are called *galls*. The necessity for grinding out these galls, much increases the labour of producing a flat surface on the slabs, the thickness of which is also lessened; this it is sometimes an important object to avoid with valuable marbles, which are occasionally cut into veneers for inlaying, not exceeding one-eighth of an inch in thickness.

The length of the traverse of the saw is generally about 20 inches, and a saw is therefore chosen that is about 2 feet longer than the block to be cut, as the shorter the saw that can be efficiently used, the more firmly the blade is held. When two small blocks have to be cut, they are frequently placed end to end with the intended cuts in the same plane; and to prevent the sand and water, called the *feed*, from flowing out between the stones, the interval is filled up with straw rammed in firmly between the two blocks; in the case of light-coloured marbles clean shavings are used for this purpose, as the straw would stain the surfaces, unless the slabs were washed immediately afterwards.

After the marble has been cut into slabs with the stone saw, if it be required to reduce it into smaller pieces, or narrow slips, such as shelves, or the sides of chimney-pieces, the slab is laid on a bench, having a flat surface of hard stone, or marble, called a *rubbing-bed*. The lines indicating the margins of the required pieces are marked with the straight edge and black, and the lines are chased with a narrow chisel, as for the entry of the stone saw, but the cutting is effected with smaller blades, called *grub-saws*, shown in fig. 140; these consist of plates of iron from one-twentieth to one-tenth of an inch thick, from 6 inches to 4 feet long, and 6 to 8 inches wide when new. The blades are not stretched in a frame, but are stiffened by having their upper edges clamped between two pieces of

wood extending their whole length, and measuring about 2 inches wide and 1 inch thick, the whole being held together by means of ordinary wood screws, passing through holes in the plate, so as to form a wooden back something like those of the dovetail saws, which also serves as the handle by which the grub-saw is used.

FIG. 140.



The blade should always be shorter than the length of the cut to be made, as should it be longer it would be worn hollow from the greater amount of rubbing to which the middle would be exposed; but when the grub-saw is much shorter than the cut, it is liable to be worn rounding in its length. To counteract this tendency, the blades are sometimes filed at every 4 or 5 inches, with angular notches about $\frac{3}{4}$ of an inch deep, which also allow the feed, or the sand and water, to reach the bottom of the cut with greater facility and the grub-saws are consequently considered to cut rather faster for the notches. The width of the iron blade measured to the wooden back, limits the depth of the cut to which the grub-saw can be applied, and in selecting a saw for any particular piece of stone, preference is given to as narrow a blade as can be fairly applied to that thickness, as when the blade is wide it is rather feeble sideways and it is besides more liable to be twisted from the perpendicular when rubbed backwards and forwards in the cut, which is done with one or both hands applied on the back of the saw near the middle of its length.

Slabs of marble or stone that are required to have flat surfaces, after having been sawn to their respective sizes are laid upon the rubbing-bed with that side upwards which is to be ground flat, and a smaller slab of stone with a tolerably flat surface is then selected to be used with sand and water as the grinder. The size of the grinder or, as it is called, the *runner*, depends upon the size and condition of the work to be ground; if the slab be large and moderately well sawn, as large and

heavy a runner is used as the workman can conveniently push backwards and forwards; if the work be rounding in the middle, a smaller runner is employed; and if the slab be hollow in the direction of its length, a long narrow runner is used; the selection depending upon the condition of the slab and the judgment of the workman.

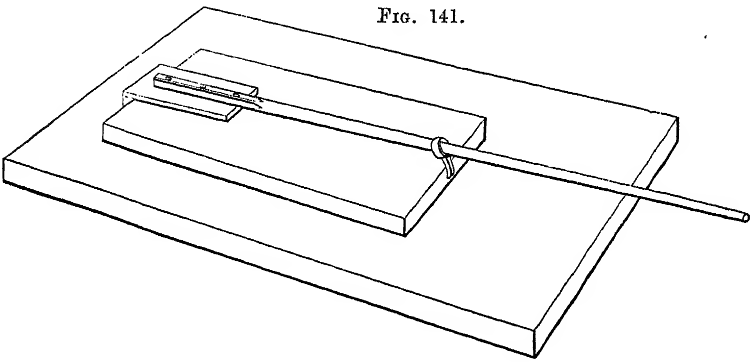
The kind of stone used for the runner is partly dependent upon the character of stone to be ground, but, generally speaking, the runner should be the harder stone; indeed, two soft stones, such as Portland, if ground together would hang to each other to such an extent as very materially to increase the labour of grinding. Portland stone is therefore generally ground with a runner of York stone. York stone and marble, however, are ground with runners of the same material as the slab, but it is better that the runner should be of a harder variety.

The stone used as the runner becomes itself ground flat in the process, and advantage is taken of this circumstance to grind slabs of moderate size, by using them as runners for larger slabs, the two stones being ground flat just as readily as one. Sometimes iron rubbers or runners are employed, and these have the advantage of retaining a much greater accuracy of form; they are far more durable and the sand and water can be applied in a more regular manner, as the iron runners are frequently made with a raised rim around their upper surface, so as to form a kind of tray, within which the mixed sand and water is placed, and the flat surface constituting the bottom of the tray is perforated with holes, through which a constant supply of sand and water is admitted to the grinding surfaces.

Of whatever material the runner may consist, it is provided with a handle of sufficient length to enable the workman to traverse it over the entire surface of the slab; if the runner be large and of stone it is in general held as in fig. 141. The end of the long handle is nailed on the upper side of a piece of board about one foot long and nine inches wide, which has a slip of wood about two inches wide nailed on its under surface, to rest against the one end of the runner, which is retained at the other end by a loose iron ring about 1½ inch wide provided with a tail-piece. The loose ring called the

hook is slipped up the handle until the tail-piece is stopped by the stone, when from the angular position assumed by the loose ring its edges slightly penetrate the handle and prevent its return, the runner is thus securely grasped between the

Fig. 141.



wooden stop and the iron tail-piece. If the runner be of iron, the handle is generally passed through two holes cast in its projecting ends, or otherwise two upright pieces are cast on the back for the reception of the handle. For small runners the handle is sometimes fixed at an angle, and sometimes vertical, as mentioned under the head Rubber, Article 2.

In grinding the flat surface of a marble or stone slab, the runner, plentifully supplied with sharp sand and water, is pushed backwards and forwards in all directions over the face of the slab, the flatness of which is frequently examined with a straight edge applied in all positions upon the surface, but principally upon the four margins and the two diagonals of the stone, and, as the slab approaches a flat surface the sand is gradually changed for finer kinds, according to the quality of the finish required on the stone: for marble, the last process of smoothing prior to the commencement of polishing is in London effected with silver sand, which is generally obtained from the neighbourhood of Croydon. The smoothing should be continued until all the marks made by the saw and the coarser sand are entirely removed, and the slab presents a uniformly smooth surface; the last marks to be eradicated in the smoothing are generally those called *stuns*, made in sawing the marble by coarse particles of sand getting between

the side of the saw blade and the saw kerf, which are sometimes then forcibly driven into the surface of the marble and cause specks that, unless removed, greatly impair the appearance of the work when polished.

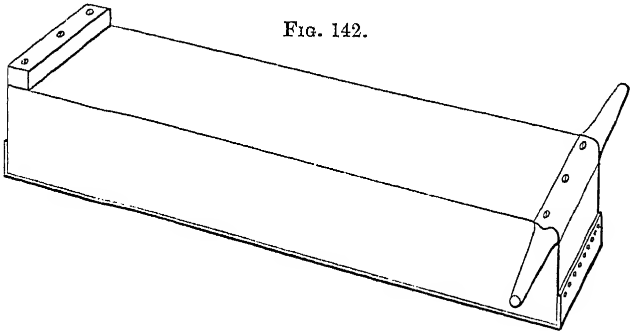
Single pieces of marble of a moderate size and weight, say not exceeding 18 inches square and 1 inch thick, are groùnd by laying them face downwards upon a slab supplied with sand and water; the marble to be ground is rubbed by the hands in all directions over the slab, but chiefly in the form of a figure of 8, to insure its being ground equally, the path in which the marble is rubbed being occasionally reversed. But when several small pieces of marble have to be ground flat, such as the squares for a tesselated pavement, it would be very tedious to grind them separately, they are therefore arranged close together and face downwards upon a large flat stone. Plaster of Paris is then poured over their upper surfaces, and a long stone a little narrower than the width of the pieces, called a *liner*, is laid over the whole, which thus become cemented together with all their faces level, notwithstanding that they may be of irregular thicknesses. The whole are then ground together as a runner upon a slab of marble, and the liner being narrower than the squares, allows of the two edges being ground as explained in the next paragraph.

For grinding the rectilinear edges of marble, large slabs are propped upright against some temporary support, and narrow rubbers of stone or iron supplied with sand and water are applied to the edges. Narrow pieces such as shelves are placed edgeways upon flat slabs, and rubbed lengthways by one or two men.

After the smoothing with silver sand, marble works are rubbed with pieces of first and second gritstone, sometimes with pumice-stone, which, however, is not generally used on account of the expense, and the grounding is completed with pieces of snakestone, as mentioned in the Catalogue. MARBLE, Article 1. The pieces of gritstone and snakestone are not laid flat upon the work, but are held edgeways at an angle of about 50 degrees, and rubbed in the direction of their breadth, much the same as in sharpening a plane iron or chisel. Flat surfaces in marble are lastly polished with the

block, or wooden rubber covered with thick felt, described under the head RUBBERS, and shown in fig. 142. A piece of stone nearly as large as the block is generally placed upon it as a weight, and the block is rubbed backwards and forwards. The proper succession of polishing powders is mentioned under the head MARBLE, but it should be observed that crocus

FIG. 142.



is only applied upon dark-coloured varieties, as it stains the light-coloured or statuary marbles, and for the last finish the London workmen prefer coarse linen rags.

The curved and rectilinear edges, as seen in plan, combined along the margins of slabs for marble tables and mantel pieces, first marked out and chipped roughly to form, are sometimes ground to their finished outlines with emery wheels, after which they are smoothed square to the surface of the slab with rubbers, or are worked into mouldings. The emery wheels used for this purpose at M. Boors' Stone Works at Namur are of a coarse grain, 1 to 2 inches wide upon their flat edges by 30 inches diameter, when new, and are used until worn down to about 9 inches; they are mounted like ordinary grindstones, but revolve at a rapid pace and are kept constantly wet by a stream of water falling on them and the work. The marble lies on a flat support or table which is of sufficient length to always entirely support it; the table is also adjustable for height that the slab may lie parallel with and in about the plane of the axis of the emery wheel, and the slab to be shaped is pressed against and traversed past the edge of the wheel by hand. Heavier slabs are slung to a counterpoise above to allow the workman greater freedom in

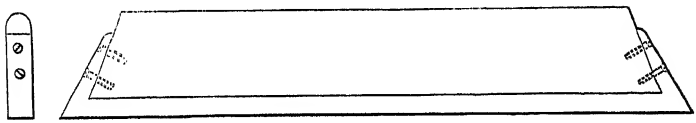
twisting them about to follow the desired curvatures, some of which are of small radius, the various outlines often meeting in internal corners; the pieces of wood, parallel in thickness, to the ends of which the slings are attached, then rest on the table to either side of the wheel.

The edges of the best class of encaustic tiles are sometimes ground to right angles with their surfaces, and these latter to exact parallelograms upon the sides of revolving emery wheels. A machine used for this purpose by Messrs. Walton, of Carrara, Italy, fig. 23, has two large emery wheels clamped against flanges on the same spindle which revolves horizontally, and, by the interposition of washers between the flanges and the emery wheels, the latter may be fixed closer or further apart to accommodate tiles of different dimensions. The upper halves of the emery wheels project through wide apertures in the surface of a table provided with a central slide with two cross pieces between which the tile is held by a wooden wedge; one edge of the tile is placed in contact with an adjustable stop on the machine before the wedge is secured, to give an equal amount of work to each wheel, and the slide is then pushed up by hand to traverse the tile between them, and this reduces two of its sides square and parallel simultaneously; but little has to be ground away, and the tiles are replaced in the slide and passed a second time between the wheels for their sides at right angles.

Mouldings in stone and marble are worked partly by the chipping chisel and partly by grinding. The drawing of the required moulding is first pricked through upon a piece of cardboard, which is then cut out to the counterpart form of the moulding, and if it be small a copy is made in sheet metal, generally zinc; counterparts made in metal for small mouldings are called *moulds*, those made in wood for large mouldings are known as *templates*, but they are both applied in exactly the same manner. The outline of the moulding is first scribed from the mould upon the two ends of the block of stone, and if the moulding is deep so that any considerable portions have to be removed, and in either a soft stone that is easily sawn, such as Caen stone, or of any valuable marble, such as statuary marble, the large pieces are removed either with toothed saws or grub-saws according to the hardness of the material; and the

saw-cuts thus made are precisely represented by the dotted lines in the section fig. 798, Vol. II., descriptive of an analogous process in working wood mouldings. If, however, the stone is hard and not of great value, the principal portion is chipped away in large chamfers; lines are then drawn on the face of the work, to denote the several members of the mouldings, which parts are worked first as square fillets and small chamfers. The contour of the moulding is then formed with small straight and round-ended chipping chisels, under the guidance of the mould and the lines on the ends of the block; the quirks of the beads and similar parts are cut in with grub-saws of suitable thicknesses.

FIG. 143.



When the mouldings have been rendered as perfect as admissible with the chisels their surfaces are completed by grinding, which is done with stone or iron rubbers having concave and convex edges for the curved parts, and square edges for the fillets and flat surfaces, sand of various degrees of fineness being used according to the progress of the work. The square iron rubbers for the fillets and square edges are made of bars of iron about 1 inch deep of various widths and from 1 to 3 feet long according to the length of the work, the bar is thinned and turned up at each end for its attachment to the wooden stock upon which it is mounted as shown in fig. 143. Small rubbers entirely of iron and from 2 to 10 inches long are used for those members of mouldings which are of frequent occurrence, such as beads and astragals, but for the less frequent parts of mouldings, stone rubbers are principally employed, from motives of economy.

The mouldings are finally smoothed and polished with small slips of gritstone and snakestone, followed by putty powder applied on the ends of soft deal sticks, they are afterwards *clouted up* or rubbed with pieces of nearly worn-out felt, removed from the blocks used for polishing flat surfaces, and the last finish is given with linen rags and putty powder.

Inlaid works in coloured marbles for mosaic and other patterns inserted in a flat surface, such as a table top, are combined and ground in the following manner. The marbles are first cut into thin sheets from one-eighth to one-fourth of an inch thick, which are cut into pieces of the required forms and smoothed on the edges by filing and rubbing. Temporary slips are then fixed down to a flat surface, within which the pieces of marble to form the pattern are arranged in their proper order, face downwards and pressed tightly together, plaster of Paris is poured over the whole, and a slab of stone, or *liner*, is laid upon the plaster, which thus cements the whole into one mass exactly the same as the single row of squares for a tesselated pavement, previously explained. When the plaster is set, the surface of the inlaid work is ground and smoothed as a runner upon a flat slab, until it presents a level surface.

The work is now laid face upwards and a second coat of plaster of Paris, and a second liner is applied to the face of the work, which is thus cemented between the two pieces of stone, the first of which is then removed. To effect this the block is laid with the first liner upwards, a rim of clay is made on the surface of the second liner, and boiling water is poured in, which soon destroys the cohesion of the first coat of plaster, then removed together with the liner, thus again exposing the backs of the pieces constituting the pattern, which are then cemented as one piece in the recess, previously prepared of the exact size in the slab of marble in which the pattern is to be inserted. If the work is not intended to be exposed to the weather plaster of Paris is used as the cement, but if the inlay is required to resist moisture or frost, the slab and pattern are both heated and cemented together with the soft cement used for marble and stone.

The cement made of rosin and bees-wax is melted in a pipkin, poured into the recess, and the pattern is inserted bodily; so soon as the cement is set the second liner and plaster are removed from the surface, but this time the application of the boiling water is not necessary as the plaster can be readily detached from the smoothed surface with a chisel applied around the edges. The entire face of the slab is now ground and smoothed to make the pattern quite level with the

margin, after which any imperfections that may exist in the joinings of the pieces are corrected with coloured shell-lac stopping or cement, and the work is finally polished as usual.

SECT. III.—THE FORMATION OF PLANE AND OTHER SUPERFICIES IN STONE AND MARBLE BY MACHINERY.

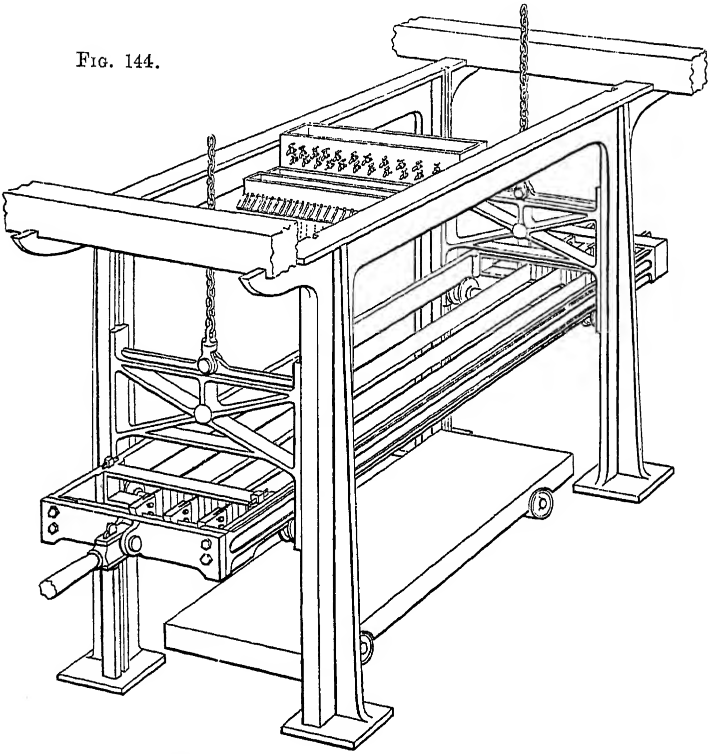
The freestones, marble and granite are all extensively worked by machinery driven by power, and, with some exceptions which widely differ, the processes followed are closely analogous in principle to those pursued by hand; the present section will deal with the usual and with some of the exceptional machine processes.

In the simplest application of machinery to sawing stone and marble, as for making one or two cuts in a large block, the construction of the ordinary stone saw, fig. 138, is closely followed, but the frame is much stronger, of squared timber firmly bolted together and stayed with chains, to constitute three sides of a rectangular frame; the place of the pole and tightening chain of the saw, fig. 138, is occupied by two fixed beams, and the saw is held and stretched by means of two clamps with screws passing through the ends of the frame, and tightened by nuts on the outside. The saw frame works between vertical guide posts to keep it upright, and is reciprocated horizontally by a connecting rod fixed to a crank driven by the engine. The connecting rod is attached to the frame by a loop, which can be placed at various heights so as always to keep the stroke of the rod nearly horizontal notwithstanding the gradual descent of the saw in the cut. These saw frames are sometimes made as large as 20 feet long, and 10 feet high, for cutting huge blocks of marble; and to prevent their great weight from pressing on the cut, they are suspended at each end by chains or slings which vibrate with the saw and are connected with a counterpoise, that is adjusted to allow of the necessary pressure for the cutting, effected with sand and water supplied in the same manner as for the stone saw used by hand, but the introduction of the guide principle renders the chasing of the stone for the entry of the saw unnecessary. In some cases smaller saws of similar construction are used for cutting thick slabs into narrow slips, and

sometimes several cuts are made at once by an equal number of saw blades, arranged in a rectangular frame that is suspended horizontally by vibrating slings, and works between vertical guide posts.

The compound horizontal sawing machine for marble patented by Mr. James Tulloch in 1824, is the earliest known

Fig. 144.



to the writer, used for cutting a block of marble into a number of parallel slabs, of any thickness, at the one operation. The iron framework of the machine, shown in fig. 144, consists of four vertical posts strongly connected together at the top and bottom, to form a stationary frame from 10 to 14 feet long, 4 to 5 feet wide, and 8 to 12 feet high, within which the block of marble to be sawn is placed. The two upright posts at each end of the stationary frame have perpendicular grooves on their insides opposite to each other, within each pair of which slides up and down a square vertical frame; to the lower end

of each of these slides is affixed a spindle carrying two guide pulleys, upon which the horizontal saw frame rests and is reciprocated backwards and forwards. The saw frame is thus traversed within the fixed framing and supported upon the four guide pulleys of the vertical slides, which latter are themselves suspended by chains coiled upon two small drums placed overhead. On the same spindle with the drums is a large wheel, from which a counterpoise weight is suspended by a chain. The weight of the counterpoise is so adjusted as to allow the saw frame to descend when left to itself, and thus supply the necessary pressure for causing the penetration of the saws.

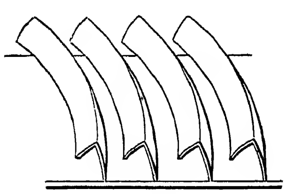
The saw frame is rectangular and from 2 to 3 feet longer than the distance between the vertical slides, in order to permit of the horizontal traverse of the saws, which is from 18 to 20 inches. To allow of the blades being fixed in the frame with the power of separate adjustment, every blade is secured by rivets in a clamp or buckle at each end; the one extremity of the buckle embraces the saw, the other is made as a hook, the buckle at one end of the saw is hooked upon a horizontal bar fixed across the end of the saw frame, and the opposite end of the frame has a groove extending its entire width, through which a separate hook provided with a vertical tightening wedge is inserted for every saw, which thus admits of being replaced without deranging the position of the neighbouring blades. The distances between the saws and their parallelism with the sides of the frame are adjusted by means of iron blocks made of the exact thickness required in the slabs of marble, the blocks and blades are placed alternately, and every blade is separately strained by its tightening wedge until it is sufficiently tense; the blocks are sustained between two transverse bars, called *gage bars*, and are allowed to remain between the blades to give them additional firmness.

The traverse of the saw frame is given by a jointed connecting rod attached by an adjustable loop to a long vibrating pendulum, that is put in motion by a pair of connecting rods placed one over the other and leading from two cranks driven by the engine. All three connecting rods admit of vertical adjustment on the pendulum. The connecting rod of the saw frame is placed intermediately between the other two, but its exact position is regulated by the height at which the saws are working,

as it is suspended by a chain and counterpoise weight, which allow it to gradually descend on the pendulum with the progress of the cut, so as always to keep the connecting rod nearly horizontal. In some cases two or four of these sawing machines of different sizes are grouped together, with the driving shaft and pendulums in the middle, and so arranged that each pair of saw frames reciprocate in opposite directions at the same time, in order to balance the weight and reduce the vibration.

One of the most difficult points in the application of these machines was found to be the equal supply of the sand and water mechanically to the whole of the cuts at the same time, and this is successfully effected by the following arrangement. Above the block of marble to be sawn, is fixed a water cistern or trough extending across the whole width of the frame, and measuring about a foot wide and a foot deep; about 20 small cocks are arranged along each side of the cistern, and a small but constant stream from each of the cocks is received beneath in a little box, a sloping channel leads from every box across the bottom of a trough filled with sand, which mingles with the water and flows out in separate streams that are conducted to each of the saw cuts. In the first construction of this feed apparatus, the sloping channels were led straight across the bottom of the sand trough, but it was then found that the water excavated little tunnels in the sand, through which it flowed without carrying the latter down. This difficulty was overcome by leading the channels across the bottom of the trough in a curved line, when viewed in plan. The form of the channels is shown in fig. 145, which represents four channels cut across the middle of their length, to show their section, from which it will be seen that the channels are made as a series of gothic-shaped tunnels supported only on the one side, and open on the other for the admission of the sand; the water flows through these tunnels, and continually washing against the convex side of the channel undermines the sand, which falls into the water and is carried down; to assist this action the attendant occasionally stirs up the sand to loosen it. There is a sand trough

Fig. 145.



and set of channels on each side of the water cistern, so that every saw cut receives two streams of sand and water in the course of its length.

The saws having been adjusted to the proper distances for the required slabs, the saw frame is raised by means of a windlass and the suspending chains attached to the vertical frames, and the block of marble to be sawn mounted upon a low carriage is drawn into its position beneath the saws and adjusted by wedges. The saws are then lowered until they rest upon the block, the counterpoise weights are adjusted, and the mixed sand and water allowed to run upon the saw blades, which are put in motion by attaching the connecting rod to the pendulum. The sawing then proceeds mechanically until the block is divided into slabs, the weight of the saw frame and connecting rod causing them gradually to descend with the progress of the cutting. To allow the sand and water to flow readily beneath the edges of the saw blades, it is necessary that the horizontal frame should be slightly lifted at the end of each stroke. This is effected by making the lower edges of the frame, which bear upon the guide pulleys, straight for nearly the full length of the stroke, but with a short portion at each end made as an inclined plane, which on passing over the guide pulleys lifts the frame just sufficiently to allow the feed to flow beneath the saws.

Mr. William Brindley, who has most kindly placed his experience and the extensive resources of his London workshops unreservedly at the writer's disposal, considers the following factors essential to all reciprocating stone sawing machines; he says: "The saw must be well strained and must descend and pass downwards through the block; raising the block of stone to give the feed by elevating screws, inclined planes or other means, placed below it, whilst the saw remains and traverses at the same level, proves unsuccessful. The saw or saws must have a very decided lift from the work at about the termination of every stroke, to permit the sand or other abrasive material to find its way beneath its edge. The abrasive material and water must be freely supplied and in ample quantities, the latter in some cases even profusely." All these requisites are thoroughly provided for in Mr. Tulloch's original machine, which remains in use and may be considered the

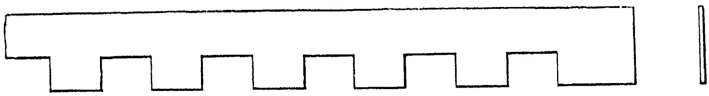
type from which many other later machines have been derived, but which differ mainly in details of construction. It is proposed, however, to notice one or two reciprocating stone-sawing machines of late date, in which these same essentials are attained in a somewhat different manner, and then to describe some modern machines successfully used for stone sawing on entirely different principles.

A horizontal sawing machine employed in America and patented by Mr. Thaddeus A. Jackson, New York, 1887, has four strong uprights with plane inner vertical faces, bolted down to a base plate and connected together above, both along and across. A frame or cage in the form of a long parallelopiped, composed of bars strongly braced together on its sides, ends and upper surface, reciprocates within the uprights, travelling on four roller wheels mounted on its side bars at about the center of its height, which run in grooves on the flat faces of long horizontal brackets or shelves fixed on the inner vertical faces of the uprights. The weight of this frame suffices to retain it in position on the brackets and for the resistance offered by the cut, and the frame is reciprocated by a crank and connecting rod at the one end. The ends of the moving frame carry vertical external bars which are rebated on their inner edges to form wide central slides, to receive rectangular carriages which travel up and down them by rollers fitting within the rebates, and portions of these carriages extend through the slides and within the frame where they terminate in blocks to which the saw or saws are strained. Long vertical screws, mounted centrally in the slides, pass through plain holes in the carriages and raise or depress them and the saws within the reciprocating frame by means of square nuts loosely fitting within corresponding recesses in the two carriages.

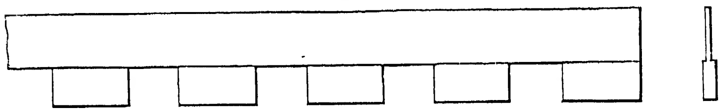
The upper ends of the vertical screws are each provided with equal spur wheels that are moved by an ingenious system of spur and bevel wheels and pinions, their spindles mounted on cross bars on the top of the reciprocating frame and actuated by adjustable links from eccentrics on the same shaft and crank by which the frame itself is traversed. This arrangement gives the feed in two ways; it partially rotates the two vertical screws automatically and simultaneously in the

one direction to lower the saw through a small space, adjustable according to the size and hardness of the stone being cut, at the commencement of every traverse, and then turns the screws in the reverse direction and through a larger space to

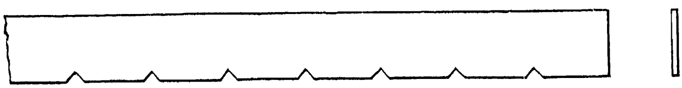
Figs. 146.



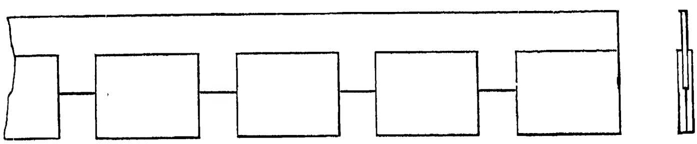
147.



148.



149.

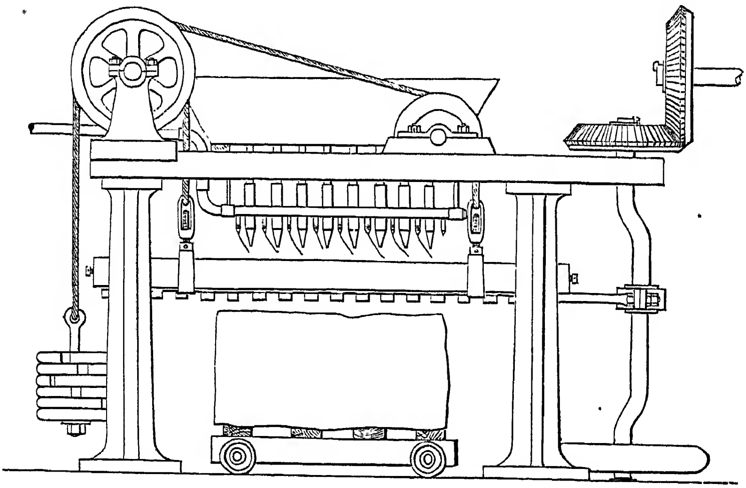


just raise the edge of the saw from the cut during its back stroke, or, it is otherwise adjusted to first raise the saw and then lower it into cut at each end of every traverse that the saw may operate both ways; and when the feed portions of the gear are disengaged, both screws can be turned simultaneously to raise the saw to admit the block to be cut.

The saw employed and previously known, fig. 146, is notched out on its straight lower edge with rectangular spaces from 4 to 6 inches wide, and of nearly the same depth, the intervals or portions of the original blade left being of about the same width as the notches; a form adopted to collect and retain the sand or chilled iron sand used. It will be seen that in this machine the frame or cage traverses on fixed supports, whilst the saws carried within it alone slightly descend at every traverse. Viewed economically, half the time is lost when the

saw cuts in the one direction only, and loss of time is not altogether absent when the saw is lifted free of the stone and returned to it at every change of traverse, when it operates in both directions; moreover, the intermittent descent of the saw when given by screws is always comparatively feeble in power, because the weight of the traversing frame cannot be used to enforce it as in machines on the principle of that just previously described, in which latter also the saw is never entirely idle.

FIG. 150.



The machine, fig. 150, patented by Mr. James Peckover, of Philadelphia, U.S.A., also in 1887, is constructed to carry one or several saws, and has some decided advantages including that of simplicity. An oblong reciprocating iron frame within which the saws are stretched by screws and buckles, fits and traverses within the plane vertical faces of the uprights of the external framing, suspended from the top from four points by means of two chains or wire cords, on the one side, which are led over one double-grooved pulley to one and the same weight, and two similar cords, pulley and corresponding weight on the other. The cords or chains are attached to the saw frame by right- and left-handed screws and loops, similar to that shown in fig. 139, that the tension of all may be severally adjusted for the saw frame to hang level; and the equal counterpoise

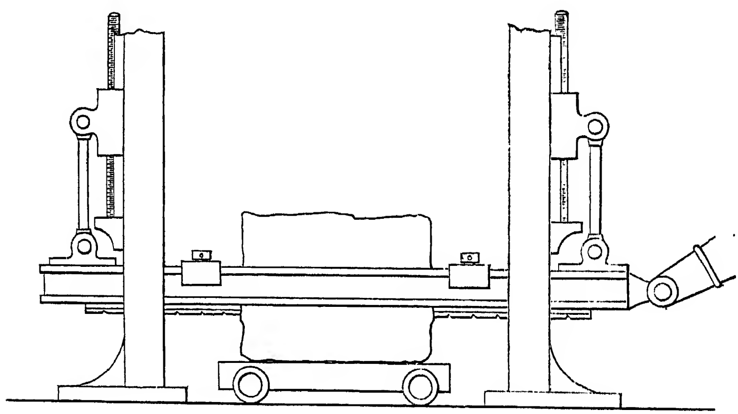
weights may be added to or diminished to allow nearly the full weight of the saw frame, or less, to rest upon the block according to the hardness of the stone being cut, and a sufficient addition to the two counterpoise weights raises the saw frame to admit the block. The traverse is given by a horizontal link jointed to one extremity of the long saw frame, the other end of which link embraces and freely ascends and descends upon a long vertical crank with short necks, mounted at the end of the outer framing and carrying a flywheel below, set in motion by a pair of bevel wheels or a driving pulley above. The arrangement of the parts, so far mentioned, is after the general model of fig. 144, but is notable for its compactness, which enables the machine to be used in a confined space.

The lift usually given to the saw is altogether abandoned, but the saw blade patented by Mr. Peckover, fig. 147, an improved form of that last mentioned, assisted by the mode of delivering the sand and water, is intended to work without it. The blade is made of two thicknesses in the one solid, the lower and thicker half being notched throughout its entire depth, and the sand and water finds its way down its thinner upper half through the intervals in the lower and beneath its edge. The difficulty experienced in delivering mixed sand and water in correct proportion is avoided by supplying each under separate control. The sifted sand is placed above in a trough with sloping sides and ends, the bottom of which has several lines of holes leading to tapering telescopic tubes, any of which lines of tubes may be plugged and others used, according to the number of saws, to allow fine streams of sand to fall directly on the saw blades. The water is supplied by a system of longitudinal pipes below the sand box, each pipe provided with numerous nozzles, any of which may be plugged or used in like manner; and each of those in use has a wire temporarily attached to it down which the water trickles to meet and mix with the sand as both reach the saw cut.

In like manner, to save space, the connecting rods, cranks and long pendulum which traverse the saw frame in fig. 144 and similar machines, have recently been dispensed with by Messrs. Dearden, at their works at Nelson in Lancashire. In their machines the reciprocating saw frame, swinging between the usual uprights, is suspended by four chains wound on two

drums placed above, and is connected to a driving crank standing horizontally by a rod jointed to one of its ends. The short shaft of the driving crank is mounted in a strong moving carriage which travels down a slide secured to the wall of the workshop; and the descent of the crank carriage is given by a long vertical screw, turned by bevel wheels at its upper end, at a rate corresponding to that at which the drums are turned to unwind the suspending chains as the saw frame descends in cutting, so that the axis of the crank and the saw frame remain throughout at the same level. Motion is given to the crank by an endless wire rope which runs vertically around two grooved wheels fixed one above close to the roof and the

Fig. 151.



other at the base of the machine below the slide, and around a third keyed on the crank; of the two first-named wheels, one runs fast on a shaft which receives the power and the other is adjustable for tension. The endless wire band is also made to embrace three-fourths of the circumference of the crank wheel, to obtain a full grip, by first passing around two grooved pulleys mounted close to the periphery of the wheel in the front part of the carriage; the vertical screw is relieved of the weight of the crank and its carriage by a chain led upwards from the latter to a counterpoise.

A different mode of reciprocation has been adopted in a machine used in the North of England, patented by Mr. John Harrison, in 1888, indicated by the diagram fig. 151. The

framing of the machine follows the usual form, and the external face of each of its four corner uprights is provided with a long vertical slide and a carriage, which latter is raised and lowered by a screw extending throughout the length of the slide, and the four corner screws simultaneously and equally depress their carriages with a slow continuous movement while the saw is cutting, by means of bevel wheels and gearing attached to their upper ends. Each pair of these carriages is connected by a transverse shaft to which the saw frame is hung by four short equal rods, jointed and moving on its four corners and on the transverse carriage shafts; the saw frame as to its width fits between the inner plane faces of the four vertical supports, it rests its weight on the block being cut, and it is reciprocated by a jointed link at one end. This suspension of the saw frame is exactly represented by an ordinary parallel rule when one limb is held stationary and horizontal, and the lower limb is swayed backwards and forwards on the centres of the two equal connecting bars; the saw, therefore, has a considerable lift, because every point along its lower edge describes an arc of a circle of a radius equal to its depth, plus the length of the rods by which it is suspended, at every swing backwards or forwards, throughout which movements it cuts continuously.

The saw blades are strained within the double ends of the frame by screws and buckles, separated by iron blocks of the thicknesses of the slabs to be cut, after the manner explained with respect to fig. 144; but by Mr. Harrison, the *gage bars* which carry the iron blocks are no longer fixed and placed at the ends of the frame, as previously, but are movable and may be clamped at any positions along it. They are fixed as close to the ends of the longer or shorter block being sawn as the necessary traverse of the saws will permit, with a decided advantage in giving far more stiffness to the portions of the saws in operation. The saw blades employed, fig. 148, are parallel in length and thickness and are cut with deep triangular notches, about four or five inches apart, all along their lower edges; they are used with sand for marble or with the *iron sand* for granite. A plentiful supply of water is given by one large horizontal delivery pipe, which is placed above and transversely to the direction of the traverse and about mid-

way between the uprights of the main frame. This delivery pipe is made to oscillate after the manner of a pendulum, on vertical pipes through which it is also supplied, jointed beneath a reservoir above; it is moved and follows every traverse of the saw frame by an eccentric and adjustable links, and its nozzles pour streams of water which wash the cuts from end to end. Emery, still and formerly exclusively used with iron or copper blades for sawing granite and the harder stones, in addition to its rapid and wasteful breaking up or pulverization under the edge of the saw blade, has a more serious objection in the circumstance that it quickly wears away the blade itself both on its edge and on its sides. The wear on the sides causes the saw to lose its parallel section and, as it is continuous, the blade soon becomes tapering and too thin upon its edge for further service. Replacing the blade only partially meets this evil because, as shown in an exaggerated degree, fig. 159, the saw cut has also become tapering. The new and comparatively thick blade, therefore, not only has to cut down through the narrowing saw kirf left by the worn blade, to widen it throughout,—so that the wear upon its edges, in thus doing a great portion of the work all over again, is even more severe than before,—but the saw is less effective, because its edge is nearly deprived of the emery which escapes into the narrower portion of the open saw cut below it.

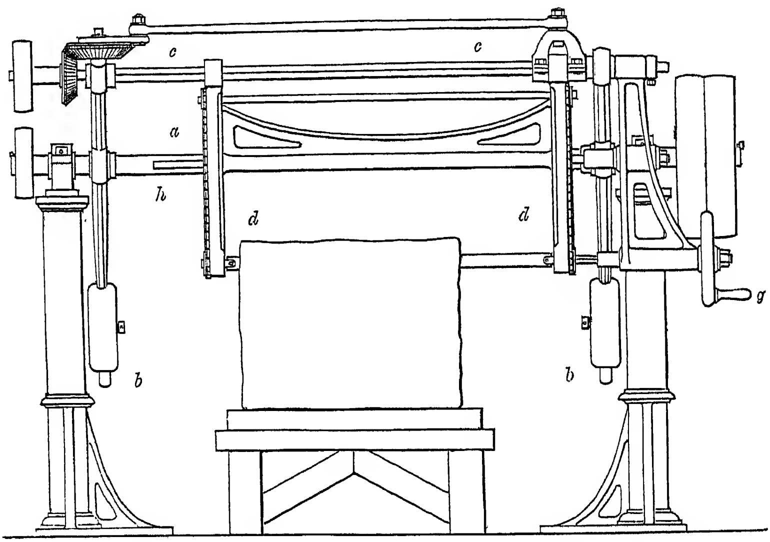
The material known as chilled iron sand now generally used for sawing granite and the harder stones in place of emery, one among other successful inventions of Mr. Tilghman, consists of small spheroidal grains of very hard, tough, chilled cast-iron, described in the Catalogue, under GRANITE, article 2. The hard iron grains are first carefully sifted to sizes, which vary about 10 to 75 thousandths of an inch diameter, about 40 thousandths to one twentieth of an inch being employed for granite; they are fed to the saw after the same manner as the sand, or as with that they are sometimes simply heaped upon the block, and they act by rolling under the edge of the soft iron saw blade more or less indenting and scoring that and pulverising the stone beneath them to powder; the debris together with much of the iron sand is continuously washed out of the saw cut by the water which, however, is supplied in less abundance than when sawing with natural sand.

Iron sand is most successful upon granite, and from these nodules being so much less easily crushed than the emery the cutting is better and quicker, so as to greatly reduce the cost of sawing this and other materials. It is found, however, that a comparatively thick saw, not less than one quarter of an inch, whether notched or plain, is required to obtain the full benefit of the rolling action of this abrasive; for this and other reasons iron sand is not generally employed for marble, for which more valuable material a thin saw blade and natural sand are less wasteful. There are also some practical difficulties in using the iron sand with marble. Any stone-sawing machine is fed with but one size of the nodules at one time, but for different varieties of stone the size is not always the same, and when the slushy mud from the powdered stone is washed and sifted to recover the iron grains for re-use, it is difficult to prevent some of the larger grains finding their way among the separated smaller sizes; and even when several machines are used for sawing stone, as in extensive workshops, so that each can be restricted to one size of the iron sand, notwithstanding the utmost care some of the different grains will still travel from the wet and mud around one machine to that surrounding another. When there is any such mixture of sizes in marble sawing, some of the larger grains are invariably arrested or jam between the sides of the thin saws employed and the surfaces of the cuts made by them, and score the latter with deep marks; this entails additional time and expense for the subsequent grinding and smoothing of these surfaces to remove the marks or *stuns*, which also reduces the thickness of the proposed slabs or sheets an amount that cannot be precisely foretold. Beyond this the rust produced in the iron sand by the water is found to injuriously stain white and the lighter-coloured marbles; this staining may be somewhat mitigated by using a much more plentiful supply of water mixed with a quantity of lime, following the practice of the cutler for prevention of rust, but the evil cannot be altogether avoided.

Both plain and notched saws are employed with iron sand, one of which latter, much used, fig. 149, consists of a plain blade about one eighth of an inch thick, embraced by pairs of rebated oblong pieces, rivetted to it and each other, at regular

intervals all along its lower edge; the combined thickness of these pieces being about one quarter of an inch. This saw blade can be more readily constructed and repaired than its predecessor, fig. 147, and it works better because the added pieces extend some way up the sides of its thinner foundation blade and form channels thereon, down which the iron sand more readily finds its way to the cut. The weight of the saw frame must in all cases rest upon the work and the more heavily the better, this being absolutely necessary to obtain the full action of the iron sand.

Fig. 152.



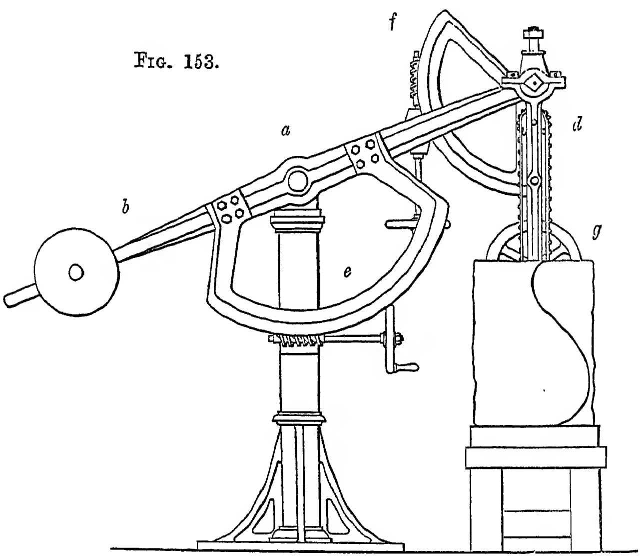
Figs. 152 and 153 indicate the construction of a horizontal reciprocating stone sawing machine for cutting rectilinear mouldings, patented by M. Armand Auguste, Paris, 1879, in which the form of the carpenter's ordinary bow or turning saw has been closely copied, and the movements given to it by the workman's hand very ingeniously provided for. The working parts of this machine are all carried on two uprights, firmly planted on spreading feet and braced together by a girder, not shown in fig. 152, at their upper ends, above which latter the main driving shaft, *a*, with fast and loose pulleys at its right hand end, runs in bearings. Two long counterpoise levers, *b b*,

solidly connected together in one plane by straight and diagonal braces, the levers alone being shown in the illustrations, move on the main shaft as on a center but without endlong movement upon it, and carry a long square shaft with cylindrical extremities which latter extend through and turn in bearings fixed in the upper ends of the levers; and on this square shaft, *c*, the saw frame hangs and moves, and together with the mechanism by which it is reciprocated, is counterpoised by adjustable weights which are fixed and slide on the lower ends of the levers. The saw frame, *d*, *d*, a virtual copy of the wooden saw frame, fig. 708, Vol. II., has two long vertical sides connected together by a central horizontal rib with flanged bracings strongly made in one solid in cast iron; the jaws for the saw have cylindrical necks which pass through the lower ends of the sides of this frame, and the upper ends of these sides terminate in square bearings, with adjustments for wear, by which the saw frame hangs and travels to and fro on the square portion of the shaft, *c*. It is set in motion from a pulley keyed on the left hand end of the main shaft, *a*, by a band to a second pulley fixed to a bevel wheel, which two latter, as a sleeve, revolve together on the cylindrical end of the square shaft, *c*, and drive the companion bevel wheel which is mounted on the top of the left hand counterpoise lever, *b*, with its axis in the line of the length of the lever. The face of the second bevel wheel carries an adjustable diametrical slide and pin, from which eccentric a long lever extends to a pivot on the top end of the more distant side of the saw frame; and the distance between the two band pulleys being always the same, the saw frame reciprocates whether it be vertical or hanging at any other angles.

The counterpoise weights which slide on the ends of the levers, fig. 153, are adjusted to nearly balance the saw frame, which latter has thus a small tendency to descend of itself and rest its weight upon the stone, and the motions given to a bow saw by hand in following a curved line are provided as follows: A circular rack, *e*, struck around the main shaft, *a*, as its center, is attached to the right hand long lever of the lever frame, *b*, and is actuated by an endless screw which is fixed to the upright of the machine and terminates in a wheel handle; this partially rotates the lever frame on its center, *a*, in either

direction to raise or depress the saw, quasi-vertically. A similar rack, *f*, struck around the axis of the square shaft, *c*, is keyed to the latter at its right hand end, and the endless screw and wheel handle by which *f* is moved is fixed on the neighbouring long lever, *b*; this second rack partially rotates the square shaft, *c*, and more or less inclines the saw frame either way from the vertical position. Lastly, to place the saw blade itself parallel with, or to stand at any angle to the sides of the saw frame, the jaws within the frame to which the saw is strained have cylindrical necks to which on the outer sides of the saw frame, are keyed equal star pinions, two similar are keyed to the ends of a long rod which passes

FIG. 153.



through and turns in bearings in the upper ends of the saw frame sides; all the pinions are of the same size and the pair on either side are connected by endless chain bands. The set of pinions is turned to shift the saw blade round by the right hand jaw, the cylindrical neck of which is prolonged and filed square and reciprocates within a corresponding aperture in a long cylinder which terminates in a wheel handle, *g*; this cylinder is contained and rotates within a fitting bored in the solid at the lower and horizontal end of a triangular shaped

frame, fig. 152, the narrow upper end of which frame is bored out to thread on to the cylindrical portion of the square shaft, *c*, beyond the right hand side of the lever frame, *b*, upon which it is retained by a collar. The triangular frame is also provided with a fixed horizontal guide rod, *h*, which passes through the central rib of the saw frame, the latter reciprocating upon it; hence the triangular frame always remains parallel with the side of the saw frame but is without endlong movement, so that the wheel handle, *g*, remains in one plane. The narrow saw blade used for the softer stones is cut with triangular teeth, as already described for the saws used by hand on similar materials, and for the harder stones a plain edge is used with sand and water.

The saw is made to follow a curve of the character of that sketched in fig. 153, which is first marked in black on the end of the block of stone, by continued intermittent slight movements given to one or other of the three wheel handles, all of which latter are close together within easy reach of the operator; the block when cut into its moulding is used as one piece, or it may then be divided into narrower pieces, and when desirable, the stone is mounted on a revolving table to shift it round to cut similar mouldings on its several sides to mitre at angles.

For their necessary strength and permanence the saw blades used in fig. 152 are usually not less than about one inch in depth; hence the curved and more especially the concave members of the mouldings around which it has to travel cannot be of small radius, and when sawing a complete moulding by one continuous cut, it is also difficult to saw out the sharp angles of the flats and fillets by which the curved members are usually separated. These external and internal angles, however, can be readily obtained first of all, by making vertical and horizontal cuts to remove pieces from the block—as already described in sawing soft stones by the hand tools; but in cutting continuous lines the machine is necessarily nearly limited to simple curvatures, for these last and for the bosting out or preparation of mouldings in the soft Caen and Bath stones to be subsequently finished, the machine with the toothed saw is principally employed. With marble and the harder stones a more serious objection was found, in the great

difficulty of inducing a sufficient supply of sand and water to find its way down the curve in process of cutting and beneath the edge of the plain saw used, and for a time prevented the use of the machine on these materials. This difficulty has been removed by the introduction of saws armed with diamonds, which may be said to have completed this ingenious machine; at present the thin flat saw blade is replaced by the diamond pointed fretsaw, fig. 400, a slender steel blade of tapering section, from a quarter to three-eighths of an inch deep and but one-eighth of an inch thick at its wider edge, now used, with a profusion of water, for both hard and soft stones with great success. The diamond saw cuts very much more rapidly, it follows quicker curvatures and more elaborate mouldings and, owing to the projection of its diamonds beyond the edge and both sides of the blade, it requires less turning in the jaws of the reciprocating saw frame.

Adaptations of the endless-band saws so generally used for wood have been tried in many forms for sawing stone, but have never attained equally or even thoroughly successful results. In one of these stone sawing machines, patented by M. Antoine Jeansaume, Paris, 1883, the general arrangements of the original French wood band saw have been closely followed; the machine has one massive upright which terminates above in a long horizontal arm cast with it in the solid, which projects at right angles over the surface of a platform through which the saw passes vertically downwards, and upon which platform the block of stone is slowly traversed by a screw and slide. The band saw is led around three large wheels, one supported at the end of and standing parallel with the horizontal arm, a second of the same diameter, beneath the platform, with its axis precisely beneath that of the first, and the third again above, provided with a shaft for driving, mounted behind the elbow formed by the upright and the horizontal arm. All three wheels are slightly rounded on their peripheries and are provided with narrow flanges to prevent the possible escape of the saw, all are in one plane, and the bearing of the first-named is provided with vertical adjustment to strain the band saw. Two small horizontal rollers at the end of an arm which is adjustable for height upon the upright of the machine, so that they

y be placed just above the surface of the block being sawn, ss the sides of the iron or steel band saw to stiffen it and ck its vibration as it enters the stone. Two similar small ers placed behind the upright embrace the sides of the saw it passes upwards, and close above and at right angles hem there are two other small wheels or rollers of hardened l, one grooved and revolving against the back of the saw the other, which is adjustable so as to press against edge, is cut as a milling wheel to continually roughen or the edge of the saw that it may the better hold the sand; method of scoring the edge of the blade has proved of siderable service and has since been frequently employed.

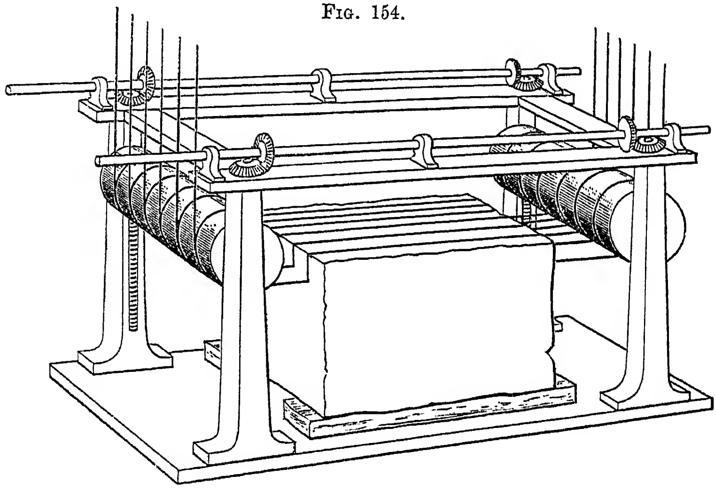
'he initial difficulty felt in the frequent breaking of the less band saw when used for wood, which accident arises in at measure from the continued compression of the one side the blade and the stretching of the other in its constant sage around the wheels, is augmented by the increased kness of the saw blade required for stone, and is a main ong other reasons against the complete success of band saws en employed for stone; and moreover, band saws have n virtually replaced by the superior advantages of the end- wire cords, now to be described.

'he introduction of an endless helicoidal wire cord to lace the saw in sawing stone is due to M. Paulin Gay Paris, who patented this ingenious method and a machine its application in 1883; it has been completely successful is used both in the original form and in other machines to ch it has been applied. The cord finally adopted by Gay and now used for marble and hard stones is composed hree steel wires, about one tenth of an inch in diameter, sted hard around one another, like a three strand cord of a ner slow spiral, and is found to hold the sand better than other. A single wire of square section twisted spirally upon lf, and wires of other sections and materials were also d singly or twisted in cords; it was considered that the ix of the square section would retain more sand, but it was nd that the corners were rapidly worn away and rounded hat it became less efficient in this respect, and also that the it was less strong in all the single wires than in the three ind cord now used. The joint must be amply strong

enough to withstand both the wear and the tension to which it is subjected, and obviously, it must be nowhere any larger than the diameter of the cord itself; with the latter it is made as follows:

Each end of the wire cord is untwisted for about two or three feet and with care not to disturb the twist acquired by the individual strands; two opposite strands are then shortened, their ends partially filed away to a long slope on opposing sides and the two are brazed in a lap joint. Of the two remaining strands at either end of the pair first joined,

Fig. 154.



one is cut off rather short and the other is left of its original length; the shorter ends are then sloped off with the file and carefully retwisted back into their places around the spiral of the joined strand. The long strands are next twisted back into place in like manner, then sufficiently shortened and filed off to just meet the short strands and finally brazed to them. The joinings of the separate wires are, therefore, at a considerable distance from one another and the joint, of the same size as the cord, is effectually strengthened against fracture from tension by the considerable length that the wires coil around one another between the three points at which they are brazed.

The frame of the machine, fig. 154, has four hollow uprights

bolted down to a solid base plate and connected together above by a flat rectangular frame, all in iron. The uprights contain vertical screws working in long nuts, shaped to travel within and also upon external slides made on the inner vertical faces of the uprights, and these nuts carry the axes of the shafts of the drums or wheels for the wire cords. Composite drums are employed made up of narrow discs with angular grooved peripheries for the cords to run in, with thicker or thinner plain edged *gage* discs interposed to separate the cords to the widths of the slabs into which the block is to be cut; these sections are threaded on the shafts by their central apertures, and they are also all bored with one or with two additional plain holes placed on their diameters at about the center of their radius, through which long bolts with external nuts pass to clamp them all together into one long cylinder. For less precise division of blocks into thicker slabs when fewer cords are employed, angular grooved wheels are placed at the required distances and are keyed on the shafts. The vertical screws are provided with bevel wheels which are driven simultaneously, and at a more or less slow rate according to the dimensions and hardness of the block under operation, to give an equal and parallel descent of the drums as the cords cut their way through the stone, and when the screws are reversed in their direction of motion they raise the drums to allow the block to be placed in position; the sand or the chilled iron sand and water is plentifully supplied in the usual manner, several streams descending on the block above each cord.

The helicoidal wire cords descend from and are led again upwards to two other drums corresponding to those shown in the figure, which revolve above attached to the ceiling of the workshop, the left hand of which upper drums is driven to set the cords in motion; and thence each cord is led away around two smaller but much longer drums to separate weighted tension pulleys hanging below the last named pair. The drums in the frame of the machine and the two pairs above all stand parallel with one another, but of the two first named upper drums that on the right hand is fixed a little higher up than that on the left or driving drum, so that the cords just escape touching the latter as they travel from the right hand drum to the lesser drums above the tension pulleys; and these lesser

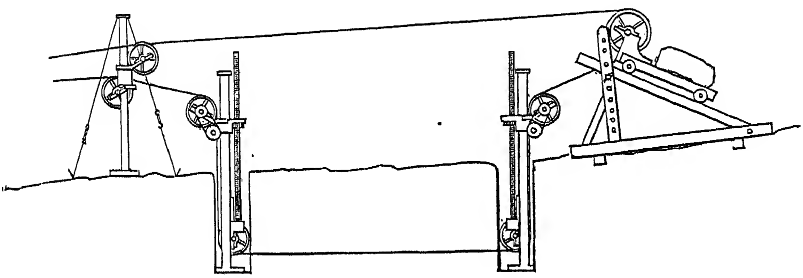
drums have the axis of that to the left placed a little higher than that of its companion, for the same purpose. The wire cords travel parallel with one another from the one upper drum throughout the parts of the machine shown to the other upper drum, but beyond these points they spread out fan-shaped from the upper drums to the long pair of small drums, in order that their increased separation may afford sufficient space below for the weights of the tension pulleys on each individual cord.

With the view to economize space all the upper drums were originally placed close to the machine, and the endless cords, therefore, had a comparatively short circuit; with the machine so arranged, although the stone was cut by the cords with facility, the work was subject to vexatious interruptions from their very frequent breaking. It was apparent—notwithstanding their greater flexibility—that the wire cords deteriorated from their constant bending around the drums, in a less degree but in the same manner as the endless-band saw blades. This physical difficulty, however, was at once and satisfactorily removed by placing the upper drums higher above the machine and the smaller drums and tension pulleys at some thirty feet distance from it; so that the endless cords were not only lengthened twice these amounts, but they then passed through a considerable proportion of their circuit in straight lines without bending. A constant antidote, as it were, is supplied by these intervals of repose or straight passage, and with the machine thus at present arranged the life of the cord, as to its endurance without fracture, is not only quite satisfactory so that it wears fairly out, but it is found to increase the more it can be conveniently lengthened.

Compared with reciprocating saws the helicoidal wire cord is less wasteful and often more rapid in its action, and it is also considered to leave the surfaces of the slabs less scored or in better condition for their subsequent smoothing and polishing. These economic results arise from the small diameter of the cord, from its continuous action, and from the facility with which it carries forward the sand, which does the actual cutting, throughout the whole length of the block under operation. The last named property is inherent to the wire cord, because, from its spiral form and from its passing around so many grooved pulleys, the cord acquires a slow and variable but con-

tinuous rotation upon its own axis all throughout its circuit. Hence the sand and water, plentifully supplied and falling down the cut on to the top of the cord, is assisted by this rotation to penetrate between the convolutions to beneath the cord so as to more or less fully surround it and, as shown by its equal wear, the rotation causes the entire surface of the cord to come into action; independently of the cord thus assisting its own feed, its convolutions are precisely suited to the work they have to perform in retaining the sand and carrying it forward along the cut, and they act the better in this respect the quicker their twist, or in other words, the more numerous turns the coils make around one another in a given length. The pressure of the cord on the block and the speed at which it travels, about ten or twelve feet per second, are neither

FIG. 155.



great, because the cord itself performs no cutting but is only the carrier of the sand which does the work, hence the slow rate of travel permits the sand a longer grinding contact and is advantageous, whilst the power required for driving is also comparatively small.

The excellent results obtained in the workshop and there being no difficulty in lengthening the helicoidal steel wire cords to any reasonable extent, induced M. Paulin Gay to apply his system of cutting to quarrying, unaltered except in the necessary details for conducting the cords to the work. In this new field the cord has been as remarkably successful, and it is now extensively used in the French and Belgian quarries, where the general arrangement of the plant is as follows:

The engine to supply the power is placed in some central position in the quarry, where it drives one or two shafts to

which are keyed numerous large groove edged wheels to put the cords in motion. Thence the cords are carried in all directions, each one supported and guided by several telferage pulleys terminating in a tension pulley, from and back to their respective motor wheels on the shafts, and often over a considerable distance such as two or three hundred yards. During the course of this circuit the cord either drives the boring tools, used for sinking the shafts to contain the guide apparatus subsequently used at the corners of the blocks whilst they are sawn; or it is employed to saw the sides and ends of the blocks themselves with this guide apparatus in situ; or it is used in machines similar to fig. 154, to divide the blocks which have been raised into pieces suitable for transportation or use. Over short distances one and the same wire cord sometimes performs both the first named functions, to which it is perfectly competent; but it is generally preferred to devote each cord to one purpose only, that of sawing or that of driving the boring tool, hence when it is necessary to arrest either of these operations it is only the one and not both which are brought to a standstill. The wire cord is confined to cutting vertically down the sides and ends of the blocks to be quarried; when possible, therefore, a position is chosen for planting the apparatus to first sink the corner shafts for these and the saw to descend to meet some natural fissure or softer stratification, that the block may be more easily detached from its bed by the wedges subsequently driven in at its corners; a precaution equally followed in all quarrying. Fig. 155 indicates the manner in which the one side of a block is cut from its bed, with the block and the surrounding rock in section.

A square iron upright, which carries the guiding and conducting wheels for the cord, is placed in the shaft or hole made at each end of the proposed block; its foot, semicircular on the side furthest from the block, agrees with the radius of the hole in the which it is fixed by wedges, and the upright is then further secured by four wire guy ropes with tension screws from its summit to the ground, these are not shown but are similar to those of the shaft of the telferage pulleys on the left of the illustration. The upright is mortised from end to end for the passage through it of the lower cord pulley, to save space in the shaft, and also as a slide for the vertical traverse

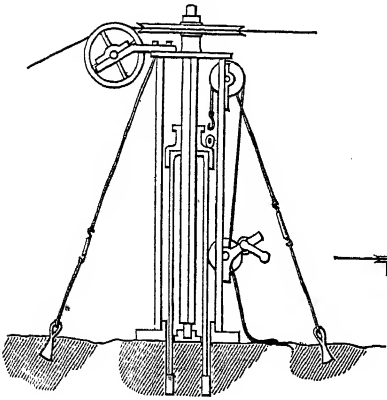
of the piece or carriage to which this wheel is attached. The slow gradual descent of the cord is given through a long vertical screw which is fixed in this carriage, and is effected by a ratchet wheel nut above, held in a mortise in the fixed mounting of the upper cord wheel and turned intermittently through a more or less small part of a rotation on the screw, according to the hardness of the stone, by adjustable levers and detents contained within the same mounting and actuated by a cam on a spindle driven from that of the upper cord wheel. The upright placed at the other end of the block is precisely similar in all respects. One telferage shaft only is indicated, but several are employed for each cord, and these differ as to the arrangement of their grooved conducting pulleys. That shown has its wheels in one plane for use in that of the out-going and returning cord; others of similar general construction have both wheels to swivel and fix to all angles to bend and conduct the cord away to the right or left; and a third variety carries a single wheel at its summit which may be fixed to run horizontally or at vertical angles. Except on the last-named, the wheels may be clamped higher or lower on the shafts, and the latter all stand upon broad feet tied down by their guy ropes.

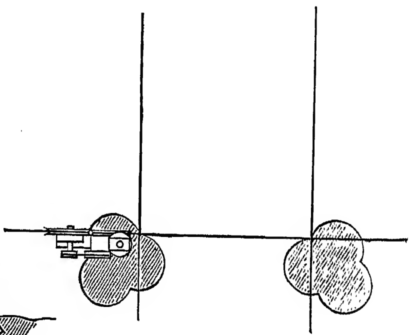
By the use of these various conducting pulleys the cords may radiate in all directions from the engine house; in fig. 155 the saw quarrying is supposed to be in operation at some distance to the right of the latter whence the endless wire cord arrives carried over several of the telferage pulleys, it is thoroughly supplied with sand and water during its passage through the block, and prior to its return passage is led around a tension pulley placed at the end of its circuit. The carriage of the tension pulley, weighted with a block of stone, travels on a portable inclined plane and ascends that by the pull of the endless cord, as the latter descends in cutting down the face of the block; the frame of this inclined plane is temporarily fixed down at any convenient spot more or less close to the work.

The steel wire cords made for quarrying are of larger diameter than those used in the machines, fig. 154, so that it is also the practice to make use of the latter when so worn out as to have become smooth, three twisted together, and several such lengths joined to one another, to make up a sufficient

length. The increased length of the circuit, its frequent changes of direction and the far more numerous grooved pulleys all tend to produce an increased rotation of the cord to that observed in the machines, fig. 154, as a consequence the cords wear very equally all around their surfaces and are also fairly permanent, usually enduring from ten to twelve days work without fracture. The wire cords will cut blocks in marble, nine to twelve feet long, to a depth of three to four inches, and in granite from two to three inches for every hour's work; applied to porphyry and the hardest stones a depth of rather more than an inch can be produced in the same time; the particular merit of the system, however, lies still more in its avoidance of waste and damage to the blocks raised than to its marked economy in time.

Figs. 155*a*. 155*b*.





The description of the helicoidal wire cord process of quarrying would be incomplete without some particulars of the tool used for sinking the corner shafts. The boring tool, shown partly in section, fig. 155*a*, belongs to the group of abrasive tools for circular forms, noticed in later pages, and consists of an open iron frame standing on a wide circular flange for its foot and is tied down by guy ropes. A crosspiece at the top carries the cylindrical neck of a vertical square shaft which runs below in a shoe placed on the rock, and the shaft is turned by one of the wire cords wrapped around a grooved wheel above its neck. An iron cylinder closed at the upper end loosely fits upon the

shaft by a square hole in its cover, and is turned by the shaft which it also descends by its own weight when in action; a deep ring or *crown*, thicker than the cylinder, is attached to the lower end of the latter and is the cutting or grinding portion. For the softer stones the ring or crown of the boring tube is jagged or it is provided with coarse saw-shaped teeth made of hard chilled iron; for marble and the harder stones the crown is of soft iron with a plain annular edge and is used with sand, emery or chilled iron sand, all with water. A quantity of the abrasive material is placed within and around the crown, and the cylinder is slightly raised from time to time from its work to allow a fresh supply to find its way beneath the edge of the grinding ring, lifted by a chain hooked on to it above and passed around a pulley to an axle turned by a wheel and pinion below.

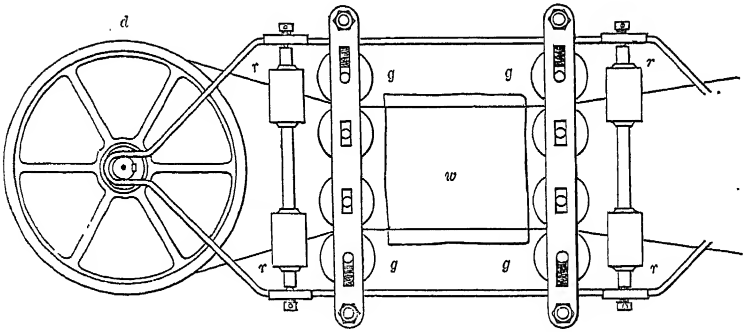
The boring leaves a solid core of the stone within the hole which has to be broken off with wedges; three of these holes are made to form each corner shaft, their centers placed in a triangle, as in the plan fig. 155*b*, which also shows one of the spiral cord conductors in position. By this arrangement the holes cross and cut into one another and their respective cores, which thus reduced, are easily broken off; the bottom of the trefoil shaft is then trimmed fairly level, or filled level with debris, to give a flat bottom for the foot of the cord conductor. The trefoil form of the shafts also permits the cord conductors to face the sides or the ends of the blocks to be quarried.

The wire cord was immediately adopted for sawing rectilinear mouldings, and the plan, fig. 156, indicates the principal features of a machine for this purpose, patented by M. Antoine Jeansaume, in 1884, and since constantly employed for marble and granite in his Paris workshops. The cord runs horizontally, strained around two large grooved wheels at either end of the machine, in which latter it passes between two sets of parallel vertical guide cylinders that are turned to the required mouldings, the work, *w*, being either a single block or several pieces of stone, clamped or cemented together, fixed on the bed of the machine between the guide cylinders.

The vertical guide cylinders, *g*, *g*, turn freely on their axles in the base and in transverse bars fixed in the frame of the machine above; in fig. 156 they are in four pairs, and in each set the

two inner guide cylinders are turned to the profile of the moulding to be given to the stone and the two outer to their counterparts, so that all projections or hollows in the curvatures of the two inner cylinders meet corresponding hollows and projections in the two outer. The inner cylinders are capable of adjustment to or from one another, in the direction of the length of the cross-bars, to accommodate the width of the particular block of stone under operation; and the two outer cylinders are pressed inwards towards the inner by spiral springs above and below, acting against their spindles, to keep the cord in light contact with them. The sand and water is supplied on the stone from above as usual.

Fig. 156.



In the arrangement of the machine shown, all four of the inner cylinders are turned to the same profile, hence the cord going and returning produces similar parallel mouldings on either side of the block of stone; the block may then be cut straight down through its center into two pieces having one plain and one moulded side, for building purposes; or the block may be mounted on a turn table to be moved through one-fourth, sixth or eighth of a rotation to produce the same mouldings to mitre on its several sides for square, hexagon or octagon pedestals and similar work. In the production of quantities of pieces of known width, as for portions of chimney-pieces, three cylinders are used instead of four; the diameter of the central guide cylinder is then twice that of the width of the moulded work, which may be a single block receiving the same moulding on either face as before, to be afterwards

divided in two pieces and then slit into slabs, or it may be several slabs cemented together and cut as a solid block, afterwards sawn down the center into two halves and then the leaves separated. A fixed plate or guide with rounded edges, is sometimes substituted for the central guide cylinder, its two rounded vertical edges shaped to the same moulding, with all the members in each exactly opposite one another, which is used with the two counterpart cylinders as before, but guide cylinders are usually preferred. The guide cylinders also all have a short portion left cylindrical at their upper ends above the profile of the moulding, and the plate guides have a short vertical edge in the same position, just sufficient to start the descent of the cord vertically to assist its first entry upon the face of the stone ; the block to be cut being wedged up to place its surface level with the point at which this cylindrical portion meets the commencement of the curvature turned upon the guide cylinder. The wire cords as already mentioned, carry forward the sand by their entire surface, hence they cut in any direction to which they can be conducted, this, and the further favourable property of their small diameter, permit the production of complete mouldings with fillets and far smaller and quicker curvatures than can be obtained in stone by any other method of sawing; and the machine, fig. 156, moreover, is as simple as it is successful. The wire cord completes its circuit around a similar large horizontal grooved edged wheel to that shown at *d*, placed a moderate distance off from the other end of the machine, the frame of which second wheel is mounted on a slide pulled by a chain and weight, to strain the cord and also to yield a little to accommodate the varying diameters of the guide cylinders. Both these wheels are bored with plain holes and are free to descend their shafts, but the plain aperture in the nave of *d*, is provided with a feather which slides down its shaft, as the latter also carries a band pulley and drives the cord. The tension suffices to keep the two large horizontal wheels at the level of the cord, and the latter is made to descend the curvatures of the vertical guide cylinders and pressed upon the block of stone, by means of the four horizontal rollers *r, r, r, r*, which rest and revolve upon it; the spindles of these pressure rollers are mounted to turn on centers in a light wrought-iron frame, the extremities of which

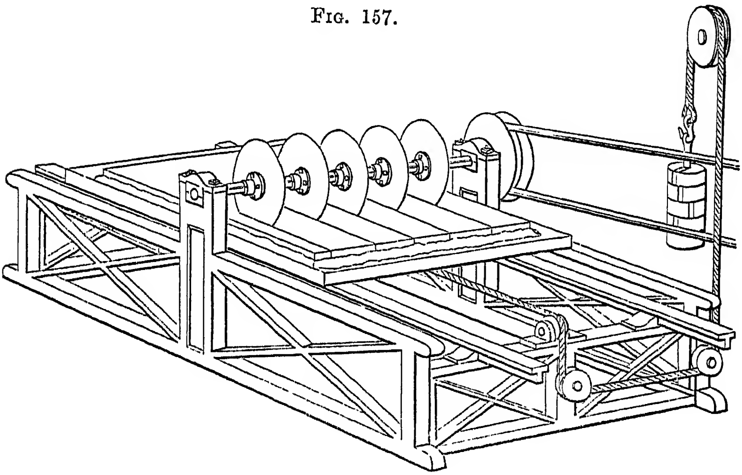
rest on the naves of the large tension wheels and give these wheels' an equal descent with the cord. Besides the parts indicated in fig. 156, the wire cord also runs through an apparatus of the same character as that mentioned page 345, by which its surface is roughened to give it a further hold upon the sand; which indenting also proves to be of marked benefit. Two small hardened steel milling wheels running vertically grip and indent the cord, which is guided and prevented from lateral escape by passing between pairs of small plain edged horizontal wheels placed close to the peripheries of the vertical milling wheels; the whole are adjustable in a frame which descends with the cord as that cuts its way down through the stone.

For cutting slabs of marble into narrow pieces, such as shelves, which is effected by hand with grub saws as already explained, a machine called a *ripping bed* is employed, in which as many cuts as may be required in the one slab are effected simultaneously by an equal number of circular saws with smooth edges, revolving vertically, and fed as usual with sand and water. This machine, represented in fig. 157, consists of a cast-iron frame about 12 or 14 feet long, 6 or 7 wide, and about 2 feet 6 inches high; two rails are fixed on the top of the frame upon which a platform mounted on pulleys is drawn slowly forward by a weight. The horizontal axis carrying the saws revolves about nine inches above the platform, and to ensure their rotation the axis is provided with a projecting rib or feather extending its whole length. The saws are made as circular plates, about 17 inches diameter when new, and are each clamped between two collars about 6 inches diameter, fitted so as to slide upon the spindle, and be retained at any part of its length by side screws.

The saws having been adjusted to the required distances for the widths of the slips to be cut and fixed by the side screws, the slab of marble is embedded in sand upon the platform, and the edge of every saw is surrounded on one side with a small heap of moist sand. The saws are then set in motion so as to cut upwards, and the platform is slowly traversed under them by a cord and the weight, which keeps the slab of marble constantly pressing against their edges until the slab is entirely divided into slips. When the saws are new they nearly reach

the upper surface of the platform, and a moderate layer of sand, just sufficient to form a bed for the slab of marble, raises it high enough to allow the saws to pass entirely through its thickness; but as the saws are reduced in diameter by wear, it becomes necessary to employ a thicker layer of sand, or to use a supplementary platform to raise the slab to the proper height. To avoid this inconvenience the spindle carrying the saws is sometimes mounted in bearings in vertical slides adjustable for

Fig. 157.

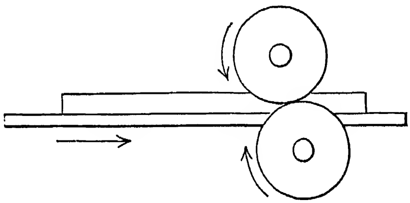


height by screws or racks and pinions, and in other machines it is placed in a swing frame which may be brought down and fixed; both of these arrangements permit the saws to pass through the slabs or to penetrate to only a part of their thickness, but the former is preferred for its greater stability.

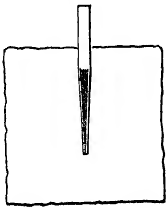
The most modern improvement in the marble ripping bed, fig. 158, has been the duplication of the spindles and saws and the adoption of the diamond to replace sand as the abrading agent. The general arrangements of the frame and methods of mounting the work remain as before, but the travelling table is split or separated into widths from end to end to allow the saws on the lower spindle to pass through it. The two spindles and sets of saws are exactly parallel one below and just in rear of the other, the table running between them, and the upper spindle is adjustable vertically that it may be

lowered to place its saws edge to edge but just not touching those on the lower. The ripping saws used for marble are from 12 to 14 inches diameter, about one-eighth of an inch thick, and have numerous small diamonds, fragments or single stones, inserted in their peripheries and on either face close to their circumference in the manner explained in Chapter XII.; during the cutting the saws require to be liberally deluged

Figs. 158.



159.



with water to keep them cool and to preserve the diamonds, and they then slit marble, granite and the harder stones with comparative rapidity and leave the work in smooth condition. The saws may be fixed anywhere along the spindles at the distances required by the width of the slips as before, and they cut through twice the previous thickness either in single slabs or two or more thinner pieces cemented together.

Sandstone, although classed as a soft stone, being practically the consolidated material used for cutting other stones, is peculiarly destructive to the saw blades, but it is also comparatively of low value, hence a wide saw kerf the waste of which would be inadmissible with marble and valuable stones is not only of little importance but may even be used to advantage. Circular, as also reciprocating saw blades with wider detachable teeth, are employed for dividing and facing blocks of sandstone and other building stone with great success; the circular saws revolving slowly, at the rate of from 30 to 50 feet of surface velocity per minute, cutting downwards and generally used without water, scoop out the wide saw kerf like a series of gouges.

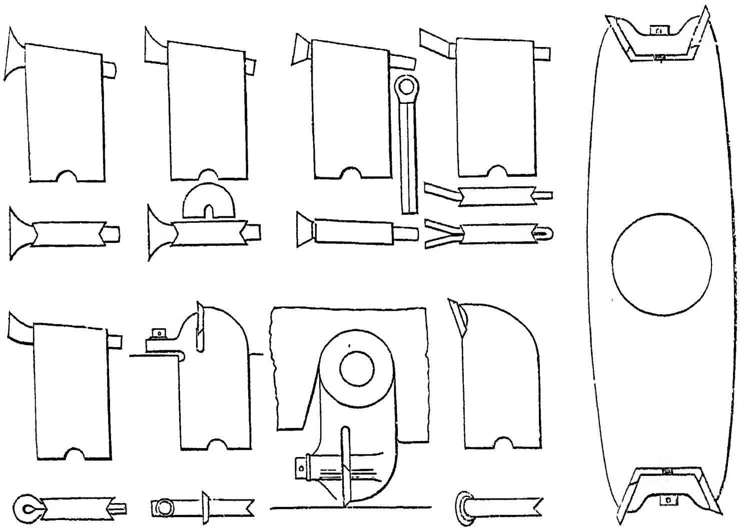
Mr. George Hunter, York Road Station Works, London, patented this method of sawing stone in 1855; numerous modifications in the details of the saw teeth have since been

made by him and others, the more important will be described. The first detachable teeth sandstone circular saws were from six to eleven feet in diameter, and were made of cast iron plates three quarters to one inch thick surrounded by wide wrought iron rims of the same thickness, subsequently they have been made of solid iron or steel plates throughout. The periphery of the saw is cut into a series of deep rectangular notches of about the same width as the intervals between them, and the upright sides of these notches are filed to a double bevel or dovetail to fit and retain the corresponding edges of the holders for the cutters or teeth, figs. 160 to 167, which are driven tightly into the notches. The forged steel cutters originally used had trumpet or bell-shaped mouths from one to one and a half inches diameter, hollowed within to give them a thin edge, and also externally to their round tapering stems, fig. 160, and were received in tapering holes bored through their holders. When partially worn the cutters are released by a blow on the small end of their stems and are turned halfway round to bring the unused half of their edges into action, and when it is necessary the holders are withdrawn from the saw blade by means of a round punch driven into a hole, formed half in the bottom of the cutter holder and half in the saw blade. The diameter of the cutter being greater than the thickness of the saw blade, the latter has ample clearance within the cut and readily divides the stone passed beneath it on a travelling table, with or without water, the crushed and powdered stone being carried down by the teeth and pushed out behind along the saw kerf by their revolution. This projection of the cutting or scraping edges of the teeth beyond the thickness of the holders and saw blade also permits the saw to be used for surfacing the sides of blocks carried past it, but for this purpose the saw blade has to be stiffened by the support of a small round edged friction roller revolving against it by surface contact, placed at right angles and towards its edge on the off side, to keep it in true rotation against the stone.

Cutters of the shape, fig. 161, bent out of flat strips of steel by forging and swageing, giving a half bell or horse-shoe mouth with thin edge and tapering stem as before, and later, similar pieces of steel bent into loops, fig. 164, gave equally good

results, but although less expensive to manufacture these forms can only be used in the one position. Hollow cutters were eventually abandoned and a solid disc or nail headed cutter, fig. 162, was adopted and patented by Mr. Hunter in 1864 to replace them. The heads of these hardened steel

FIGS. 160. 161. 162. 163. 168.



164. 165. 166. 167.

cutters are seven-eighths of an inch diameter, slightly dished or hollowed on the face and bevelled thence at an angle of about 50° for cutting edge, to their round tapering stems. Their holders measure about four inches high, two to two and a half inches wide and half an inch thick, the thickness of the saw blade, but the upper part of the projecting portion of the holder is of increased substance to afford space for the hole to receive the stem of the cutter; the apertures through the holders are also bored at a small angle to project the heads of the cutters a little to right and left of the saw blade alternately for increased clearance, but as the saw blade is thinner and the disc cutter heads of less diameter than formerly, the width of the saw cut is also less than before.

Cutter teeth of the forms, fig. 163, made of slips of steel with rectangular edges, either bent to stand alternately to

right and left, or all doubled and the ends bent outwards, held in mortises through the holders, are also used with fair results on the softer sandstones; but with these the square edges soon deteriorate and become rounded.

Another and more economical form of angular edged disc detachable teeth, fig. 165, used at the York Road Station Works since 1886, are circular discs seven-eighths of an inch diameter on the face by one-eighth thick, punched out of sheet steel so as to leave them with a small central boss on the back and a corresponding depression on the face. The holder which is in one piece of metal is deeply notched and assumes the character of a vice, a screw through a tail on the one side impinging on the edge of the saw blade and forcing the two jaws together to grip the disc, and the face of the one jaw has a round projection and that of the other a recess, to fit the corresponding surfaces of the discs for increased security; the holders are also so placed in the saw blade that alternate discs project to right and left of the latter, and the thin sheet steel discs when worn away may be turned round in the holder to present fresh portions of their peripheries to the work.

The more simple disc tooth, fig. 167, used in large circular sandstone saws at Arbroath, is both durable and quite successful. These teeth consist of bevel edged discs, slightly concave, one inch diameter by one-eighth thick, cast in very hard chilled iron in one solid piece with their holders; when worn the whole are withdrawn and replaced at small cost. This saw revolves downwards and is used without water.

In another variety of detachable teeth lately patented by M. J. L. Chevalier, 1894, and used in rectilinear and circular saws for sandstone and some harder varieties at Volvic, France, the cutters are made of hardened steel, shaped much like the carpenter's mortise chisel but with nearly parallel stems, which are inserted in corresponding plain notches placed at an angle of about 30° to the length or peripheries of the saw blades. The latter are formed of three thicknesses of sheet steel, the central being notched and the outer layers giving the sides of the mortises to receive the cutters, clearance being obtained as before by making the acting edges of the cutters a little wider than the thickness of the three combined plates composing the saw blades.

Mr. Hunter employs his detachable cutters, figs. 162—165, in a machine patented in 1886, which serves both as a ripping or dividing bed and as a surfacing machine for blocks of building stone. The spindle which carries two or more circular saws of large diameter for dividing the blocks placed below it, is driven and runs between the ends of the mandrels of two massive headstocks, similar to lathe heads, the mandrels driven by spur wheels, on either side of the table which travels horizontally between them. The table is divided into three widths all of which may traverse together, or the central width independently; long blocks to be cut across into shorter pieces stand across the table, their weight sufficing to keep them in position, smaller blocks, or pieces to be divided in the direction of their length may be clamped down on the separate widths; and the central width of the table may be run completely out and replaced by others upon which blocks have been previously fixed, for an uninterrupted succession of work to be cut to the same thickness. All the blocks stand upon wood battens placed between them and the table that the saws may pass completely through them without injury. With the saw spindle removed, thick iron surface chucks of large diameter, their peripheries armed with the cutters projecting just beyond their flat faces, are screwed on the ends of the mandrels, and these surface the vertical faces of blocks of sandstone traversed past them, resting on thicker balks of timber to mount the whole height of the block within the diameter of the surface chuck. The headstocks and mandrels stand exactly at right angles to the traverse of the table when they carry the saw spindle, but they can also be placed at a small angle to it, and this is required when they are used for surfacing in order that the cutters may only engage against the advancing stone as they descend by the revolution of the chuck and be just free of it as they ascend, to avoid all risk of scoring the smooth surface at once produced by the downward cut of the tools.

Straight reciprocating stone saws are also used mounted with various forms of these detachable teeth and holders; and the disc teeth and swing or pivotted holder, fig. 166, find further employment for producing the cylindrical edges of millstones and grindstones. The gritstone slab previously

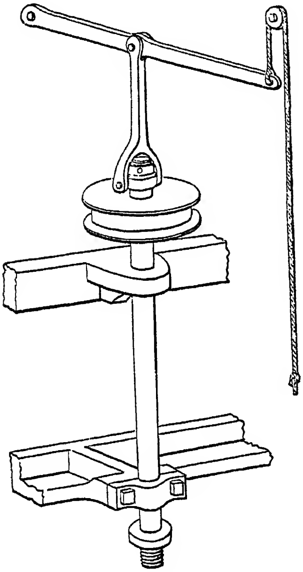
surfaced parallel in the machine last described, very roughly rounded and pierced with a hole for the eye of the grindstone, is placed on a horizontal and rotating turn table provided with a central arbor fitting this hole, and fixed down by clamps reaching somewhat less than half way up its substance. A cross slide with a long screw, similar to that of a metal planing machine, carries the tool carriage, which is traversed along it to the distance from the axis of the turn table required by the diameter of the stone; there it remains stationary, the tool holder descending in a slide in the tool carriage as the cutting progresses; two tool carriages are sometimes employed placed one at each end of the diameter of the stone. When cut half way down its round edge, the grindstone is turned over, remounted on the central pin or arbor and the edge completed from the other surface.

Circular pieces of marble, such as the tops of round tables, and other objects from about 6 feet diameter to the small round dots sometimes used in tesselated pavements, are sawn to form by means of revolving cylindrical cutters, constructed on much the same principle as the crown saws for wood described on page 802, Vol. II. The slab to be sawn is placed horizontally on a bench, and the axis of the machine works vertically above it in cylindrical bearings, which allow the spindle to slide through them so as to be elevated or depressed according to circumstances. The spindle is suspended at the upper end by a swing collar attached to a connecting rod, that is jointed to the middle of a horizontal lever. The weight of the vertical rod and cutter supplies the pressure for the cutting, and the whole is raised for the admission of the work by a rope attached to the end of the lever, and passed over a pulley as shown in fig. 169.

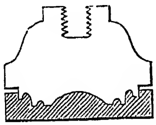
For circles of small size, the cutters are made as hollow cylinders of sheet iron of various diameters, each attached by screws to a disc of cast iron, as shown in section in fig. 171. The cutter is screwed on the lower end of the spindle just the same as a chuck on a lathe mandrel, except that the spindle is placed vertically instead of horizontally. To ensure free access for the sand and water beneath the cutter, one or two notches, about three-quarters of an inch wide, are generally made in the lower edge of the latter. For large circles, the apparatus is

made stronger than that shown in fig. 169, and the vertical spindle is fitted at its lower extremity with a circular plate, to which is bolted a wooden cross, shown in plan in fig. 172, and in elevation in fig. 173, which has radial grooves about 18 inches long near the outer extremities of its four arms. The cutters consist of detached plates of iron from 6 to 18 inches

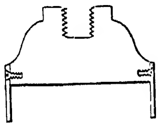
Figs. 169.



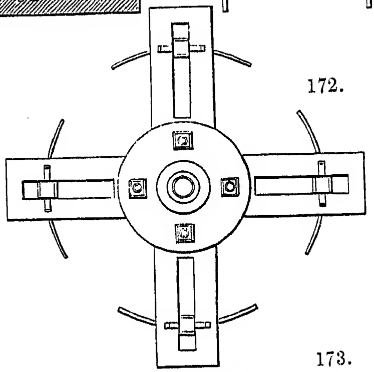
170.



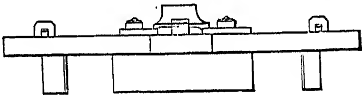
171.



172.



173.

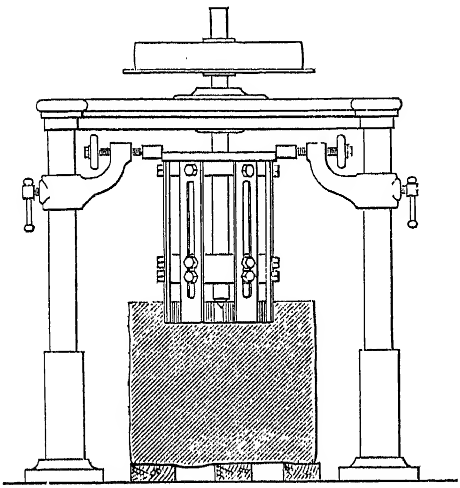


long, of various widths, according to the thickness of the work and are curved as segments of a cylinder of the particular diameter they are required to cut, and are each rivetted to a clamp that passes through the radial groove in which it is retained by a wedge. The number and length of the cutters are solely matters of convenience, as a single cutter when put in rotation would make a circular groove, and several cutters are only employed in order to expedite the process; but every different diameter requires a different curve in the cutters, which latter must all be placed at exactly the proper distance from the center of rotation. The horizontal bench upon which the marble is laid is generally a temporary structure, adjusted to suit the thickness of the object to be sawn. Works of large

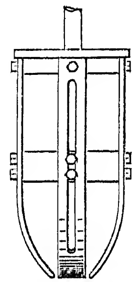
diameter are seldom more than one or two inches thick, but those of small diameter are frequently much thicker, and sometimes three or four thin pieces are cemented upon each other and cut at one operation.

An extension of these appliances for circular marble sawing is shown by figs. 174–176, which indicate the working parts of a machine patented by Mr. James Gazeley in 1881, used for cutting out large or small cores of moderate length to serve

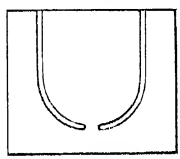
FIGS. 174.



175.



176.



for numerous purposes to which such cylinders apply, especially valuable when the stone is of rare and costly character, and also to lessen the weights of blocks of stone from which they are cut for their transportation and use in building. The machine fig. 174, has a square frame with strong upright shafts at each corner connected by cross and diagonal girders above, with a boss in the center of these latter in which the vertical spindle is driven, with its lower end revolving in a hole cut in the surface of the block of stone. The boring or cutting head is built up on two circular discs which revolve with the spindle, but are at the same time free to descend it by means of a groove cut in the spindle and keys in the central apertures of the discs. The soft iron cutters, arcs of circles of the required radius but of considerably greater length than before, are

attached around the peripheries of the two discs by bolts through plain holes to the upper, and by bolts passing through long slots made down the cutters into the lower disc, which arrangement permits the lower to be shifted closer to the upper disc from time to time as the cutters descend through the stone. Brackets clamped on each of the four uprights carry guide pieces the edges of which are curved to the radius of the upper disc, and these are severally advanced by screws into light contact with a cylindrical portion of this disc just above the top ends of the cutters. The guides are only required to steady the head at the first entry of the cutters in the stone, after which they are withdrawn so soon as the growing depth of the annular groove gives sufficient guidance; and the brackets may be fixed higher or lower on the uprights according to the thickness of the block to be pierced. The cutters are supplied with sand or with chilled iron sand and water, and the weight of the combined head gives sufficient pressure for the cut.

Cylinders or tubes of soft iron, their annular edges roughened and fed with sand and water, both from without and from within through apertures made in their upper ends, a form of tool generally used for boring, are sometimes employed instead of the separate cutters for holes less than about 12 inches diameter, for which small sizes their greater stability is of advantage. A curious development of this machine is the head fig. 175, employed for cutting partially through a block to extract a core terminating in a quasi-hemisphere. The annular hole is first ground out to a sufficient depth with the ordinary parallel cutters already described, these are then replaced by others of similar radius but with their lower ends curved inwards, which are made of steel and tempered as springs. The curved portions of these spring cutters straighten or yield sufficiently for them to pass down the annular groove already made, but on reaching the bottom and revolving and cutting with the sand and water, assisted by the vertical pressure of the weight of the head, they resume their original curved form and then increase its curvature by further bending, cutting a corresponding groove; and when withdrawn leave the rounded end of the cylindrical core, as shown in section fig. 176, attached by a neck which can be readily broken off and the core withdrawn. A block thus hollowed may have its

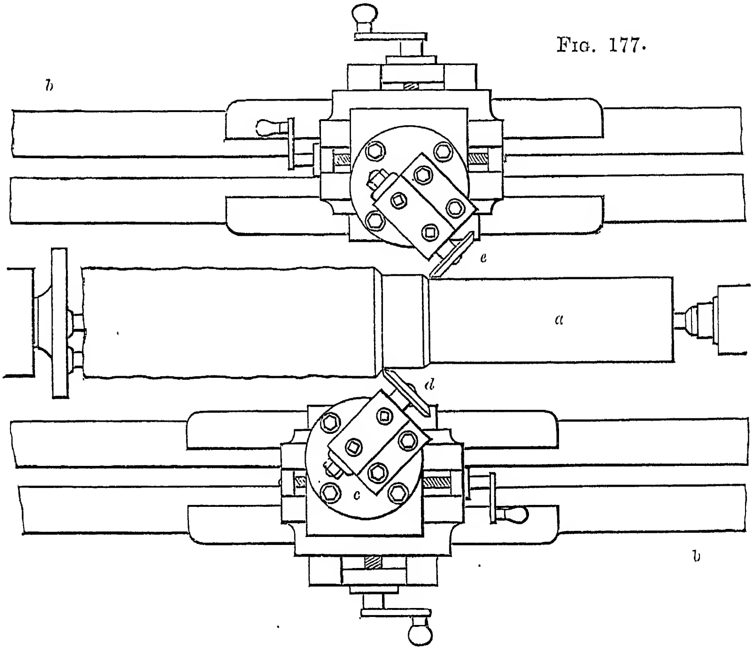
five faces worked to any shapes and mouldings for a pedestal or other purpose just as if it were solid, and standing on its pierced face the cavity is unseen; or the hollowed block may be cut through centrally to form niches. Perfect form in the rounded ends of core and cavity can hardly be expected, in addition both are scored and marked and have to be subsequently ground and finished; but the object sought of extracting and saving a piece from blocks of rare marbles, fluor spar or other valuable stone is easily attained.

In the processes hitherto described a fairly true surface is first given to the material with the pick and chisel, or the stone is sawn into blocks, slabs and other pieces, and the surfaces thus produced are then ground and polished true in the manner described in the next section; it remains to notice a series of machines for a different procedure by which the surfaces of the rough blocks are at once reduced to true superficies, smooth and ready for polishing. The machines to be referred to closely resemble the lathes and planing machines used by the engineer, with the fixed cutting tool replaced by revolving disc cutters. In the lathes for stone turning one or two revolving discs are carried on fixed stems in sliderests, and in the machines for flat surfacing several revolving discs are mounted to project from the face and near to the periphery of a large plate or chuck, itself revolving on the end of a vertical or horizontal spindle. This modern method of working stone is also precisely foreshadowed in the long previous use of the eccentric cutting frame in surfacing wood and ivory, described in Vol. V. page 185, and, it should be said, is only one among numerous examples of manufacturing processes which have been derived from the appliances used in the more delicate art of ornamental turning. The forms and action of the cupped sheet-iron and solid steel disc tools have been already explained page 163, and fig. 177 shows the application of these tools in lathes for turning stone, marble and granite, patented by Mr. J. D. Brunton, 1868; the production of cylindrical superficies properly belongs to a following chapter, but it will be convenient to describe the use of the disc tools and lathe for this purpose here, before proceeding to notice the application

of the same tools to the production of flat superficies which has in great measure arisen from it.

The stone shaft, *a*, to be turned cylindrical, is mounted between centers by deep holes made in its ends to receive the strong point and pin of an ordinary running center chuck and

FIG. 177.



the point of the popit head. The lathe head, which is not shown for want of space, is of the ordinary type, strong and driven by cone pulley and back gearing, and is mounted on a short separate bearer; the massive popit head is formed as a bridge and is bolted down on the two long parallel bearers, *b*, *b*, which are provided with main screws to traverse their sliderests and stand to either side of the work and parallel with the lathe head. The duplicate sliderests are mounted upon long saddleplates and have two slides at right angles, the upper of which carry circular movements, *c*, *c*, to fix the stems of the tools to all required horizontal angles. The disc tools used for turning granite are of hardened steel, flat and parallel, nine inches diameter by three-quarters of an inch thick, with

a broad bevel on the face side and a less acute bevel behind to leave an angular periphery of 60°; they are mounted to revolve freely on the ends of steel spindles which are held fast in square iron stems that fit receptacles on the circular movements of the sliderests. The latter traversed simultaneously by the mainscrews of the two long bearers, carry the steel discs along the work the one a few inches in advance of the other, and the discs themselves revolve by simple surface contact with the rotating work.

The turning of a granite shaft is conducted as follows,—the rough block with its corners hacked off to reduce it to an irregular octagon is mounted in the lathe, and the one disc tool *d*, is placed just beyond its end surface next the popit head, and advanced for depth of cut until its periphery stands about one inch below the most prominent angle of the granite. The lathe being set in motion the traverse of the tool *d*, rends and splits off irregular fragments from the stone similar in shape to those split off by a chisel and hammer, and from half an inch to one inch thick in their thickest parts; and when this tool has travelled some few inches along its path, the opposite tool *e*, also placed beyond the end of the block, is advanced in its turn and to a little greater depth than was given to *d*, and started in the same manner. This interval not only obtains the full and consecutive action of the two discs, but allows the same attendant to manage one or more lathes; so soon as the one tool *d*, has completed its traverse along the work the operator has time to withdraw it from contact, disengage the traversing gear and run back the sliderest, re-advance the tool for its next cut and start it back again, before he has to pass round to the other side of the lathe to perform the same routine with the tool *e*, and the two discs except during these adjustments are always operating simultaneously. Should the first pair of roughing cuts not at once produce the circular form the remaining irregularities are removed by a second, followed by others of less penetration to reduce the shaft to size; these last gradually diminished towards the close to a depth of a sixteenth of an inch or less, during which the material is removed in powder. The stem of each tool is throughout fixed at an angle that will suffice to cause the front bevel of the disc to be just out of parallelism

with the line of centers of the work, to give the angle of relief to prevent the bevel from rubbing on the work.

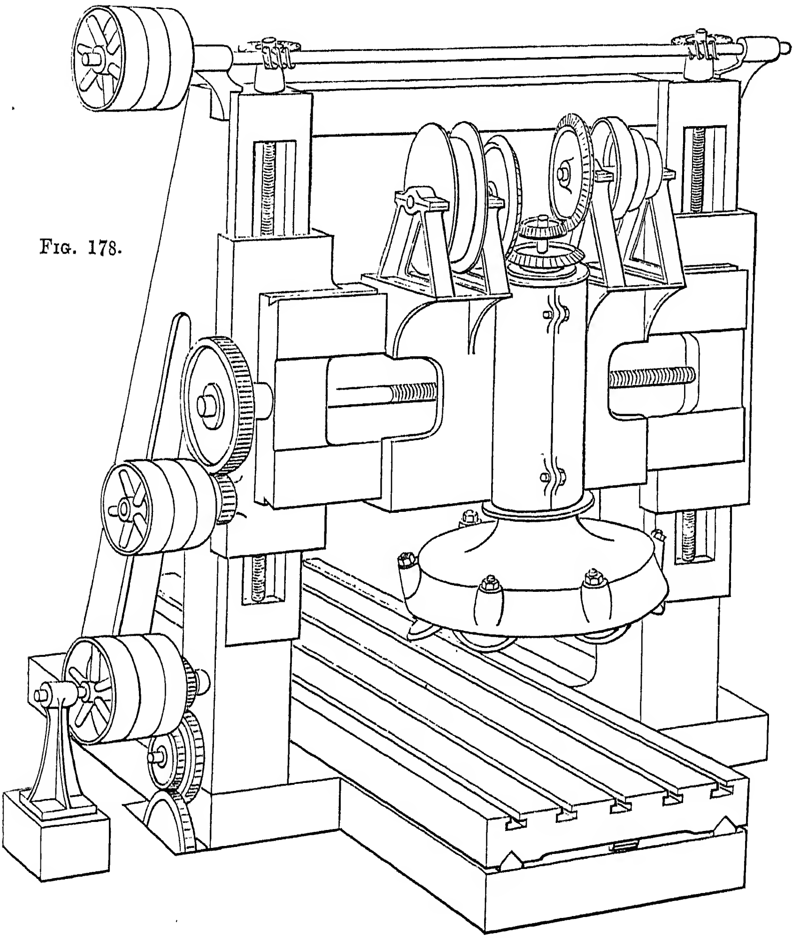
A smooth and regular surface is turned upon granite with the disc tools which is also unusually free from *plucks* or *stunning*,—small cellular cavities caused by the breaking out of the less compacted particles of this hitherto untractable material for turning,—with the result that the work is left already advanced several degrees towards the subsequent process of polishing. The disc tools are equally satisfactory upon marble; thus at the Westminster Bridge Road Works it is found that, owing to the absence of friction in the action of the disc already explained, no water is required to keep the tool cool, hence the deleterious effects of water upon the softer veins of the marble are altogether avoided; heavier cuts can be made than are possible with any other tool and it may be said with little or no pressure on the work, the pressure indeed being almost all endwise or in the direction of the length of the shaft being turned, and there is a complete absence of plucks. The traverse of the disc tool in turning granite columns 12 inches in diameter is at the rate of one inch per minute, on marble and the softer stones it is correspondingly quicker, and the disc tools perform about ten or twelve times the amount of circular dressing that can be executed by hand in similar times. All these materials may be turned dry, but for granite a small stream of water is sometimes directed on the disc.

The largest stone lathes are massive structures which will admit columns to about 20ft. long by 4ft. diameter; some have their long bearers adjustable to the line of centers for turning tapers; and with the traversing gear disconnected, the cross slides of the sliderests advance the tool for surfacing the ends of columns and flat faces, and for turning fillets and other members of mouldings at angles to the axis of the work.

In some of the machines that have been used for dressing flat surfaces on blocks of the softer stones, the disc tools are mounted after the same manner as those used in the lathe, and turn freely on short fixed studs or pivots placed around and near to the circumference of a rapidly revolving surface chuck; the spindle of the latter mounted either horizontally and the work traversed across the face of the chuck, or mounted

vertically and to rise and fall, to accommodate the thickness of the stone block and to press the chuck and discs down on the work as that travels along beneath them. The revolution of the discs, so perfectly continuous from the rolling contact with the work in the lathe, now becomes intermittent, principally

FIG. 178.



because the surface under operation is usually narrower than the diameter of the *track* or the circle described by the series of discs, every individual in which, therefore, is constantly passing on to and again off the work; hence in the machines for surfacing marble and granite it was found necessary to

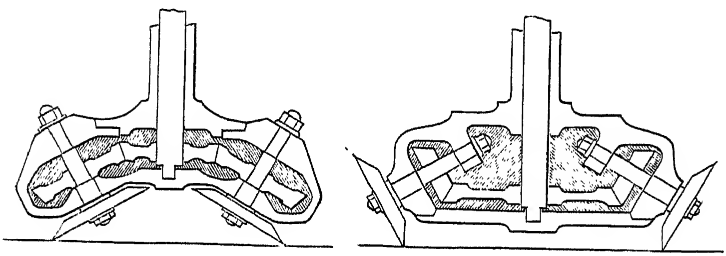
give every disc an independent rotation upon its own axis at the same time that the whole series is carried round by the chuck.

The large surface dressing machine for granite fig 178, patented by Mr. Brunton, has two massive triangular shaped uprights which stand by their long bases upon an iron platform and are connected or braced together on their sloping sides toward their upper ends. Their true vertical faces form slides which carry a piece with a vertical and a horizontal slide cast in one solid, that is raised or lowered to accommodate the thickness of the block of stone and for penetration or depth of cut, by two screws actuated simultaneously by worm wheels and endless screws upon a shaft fixed across the top of the uprights. A strong vertical plate on the horizontal slide which is traversed intermittently and in either direction by a screw terminating in a spur wheel driven by a pinion and band pulleys, carries a vertical cylinder containing the bearings of the hollow mandrel to which the chuck is attached, which mandrel is set in revolution by a pair of large bevel wheels, the shaft and large driving pulley of the one mounted in a frame bolted to the top of the vertical plate. A solid shaft runs in bearings within the hollow mandrel of the chuck and terminates below, within the hollow chuck, fig 179, in a bevel wheel to give motion to bevel pinions fixed upon the short spindles of the several disc cutters; the shaft is surmounted by another bevel wheel half the diameter of its driver, which latter with its cone pulley are also mounted on the top of the vertical plate, and all these parts being carried on the large double slide, they rise and fall with it. The chuck is 24 inches in diameter of *track* and carries six 8-inch revolving steel discs, and may be raised sufficiently to admit blocks of granite of any thickness up to three and a half feet. The stone lies on a travelling table 3ft. 6 inches wide and 9ft. long, which table is slowly traversed by a rack upon its under surface, upon the base plate 13ft. in length, by a large spur wheel driven by gearing placed at one side of one of the uprights.

The independent rotation of every disc upon its own axis whilst it is impelled along its circular path by the revolution of the chuck, essential for dressing granite and all the harder

stones and now generally employed also for the softer building stones, is obtained in the manner shown by the rough sections figs. 179-180. In fig. 179, known as an *external chuck*, the disc spindles incline inwards and the diameter of the track or cutting circle described on the work is determined by the edges of the revolving discs most remote from the axis of the chuck. With the *internal chuck* fig. 180, the spindles incline the opposite way and the discs cut by their edges nearest to the center of the chuck. The hollow cast iron shell of the chuck fig. 179,

FIGS. 179. 180.

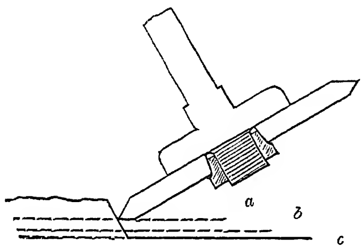


is firmly attached to a flange, the enlarged extremity of the mandrel by which it revolves, and the solid spindle which revolves within the hollow mandrel and in a bearing within the chuck, carries a bevel wheel which gears with those fixed upon the spindles of the revolving discs; in the particular chuck sketched all these wheels are of equal diameter, but in chucks of greater dimensions a larger central or prime wheel drives the pinions on the cutter spindles. The latter terminate below outside the chuck in flanges and screwed ends upon which the steel discs are secured by split collar nuts, as in fig. 181, for facilities of removal for sharpening or replacement. The split collar nut is tapered from its one face to enter the central hole in the cutter, so that as it is screwed up home on the spindle it also jams within the hole and fixes the cutter against the flange. With the external chucks fig. 179, the mandrel carrying the chuck and the solid spindle within it carrying the motor or prime wheel are driven in opposite directions, hence the cutters revolve in the same angular direction as the chuck; but when the track is given with the cutters inwards, fig. 180, the solid spindle is more frequently a fixture and the cutter spindles then acquire their rotation

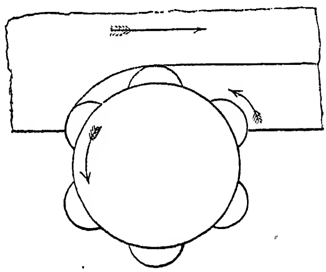
by their pinions travelling around its stationary prime wheel as the chuck revolves. By the former method the external chuck of the machine fig. 178, for dressing granite, describing a track of 24 inches diameter, is driven at the rate of 300 and its solid steel cutters at 900 revolutions per minute respectively; hence the peripheries of the discs are always in rapid continuous and perfect rolling contact with the stone throughout their passage over it and, then, perform their work without heating and with comparatively little wear.

The revolving chuck in the machine fig. 178 is shifted along the transverse slide between every cut to dress the entire

FIGS. 181.



182.



surface of the granite block a portion at a time by wide overlapping breadths, the stone being traversed lengthwise for every breadth by the table beneath it, and each breadth is surfaced by a roughing cut followed by one or two of less penetration for smooth finishing. For some materials the discs all project equally from the chuck, so that all in the series have the same penetration throughout their traverse over the block. More generally they are differently arranged as indicated by fig. 181, for the purpose of *cutting in steps*, by which method the breadth of the original rough surface under operation may often be reduced to its finished condition by a single traverse. Two opposite discs revolve with the flanges of their spindles screwed up against the outside of the chuck and their peripheries, therefore, are both upon the line *a* fig. 181, the next opposite pair are advanced by the interposition of washers behind the spindle flanges so that they reach the line *b*, and the third pair project to the line *c*, or only a little beyond the second. All act simultaneously, as the chuck revolves the

first named pair of discs attack and crop down the more prominent irregularities so far as the horizontal line *a*; the resulting and still partially unequal surface is then reduced smooth and level by the action of the second pair of discs, by a less depth of cut, so far as the line *b*; and the dressing is completed by the third pair *c*, which revolve at a still less and very small increased depth of cut than the second. The effect of this arrangement of the discs is analogous to the continually reduced advance, described page 369, given to the single revolving disc in turning marble and granite from the first roughing to the last finishing cuts. Cutting in steps prevents all plucking; the flakes first rent off from the rough block to the line *a*, do somewhat break out below the level of that plane, but this effect is rare at *b*, both from the diminished depth of cut and from the more equal resistance offered by the regular sloping edge of stone left by the action of the first pair, and ceases on the finished surface *c*, from the increased height of the approaching sloping edge and the small penetration of the third pair of discs. The six discs may be otherwise arranged to stand at two depths only, and in larger chucks carrying greater numbers in sets of four, six or more penetrations, and the finishing discs, as meeting the least resistance, are also usually ground to more acute angles to their improvement as finishing tools.

The first breadth taken in dressing granite is comparatively narrow and is traversed with the axis of the chuck well beyond the edge of the block, as indicated by the diagram fig. 182; the peripheries of the discs then roll on to and leave the edge of the block at less than a right angle in respect to its length, which appears essential to the production of a good arris; the latter is also the more sharp and clean where the chuck rotates so that the discs revolve to travel *off* the stone as that advances, as shown by the arrows. The succeeding breadths are made with nearly the full diameter of the track, overlapping one another, until the last, which overlapping on the other side, is again narrow with the axis of the chuck beyond the edge of the stone, as for the first. The mandrel of the chuck is also placed very slightly out of the perpendicular for the purpose of giving the chuck a trifling list, but no more than sufficient to throw the action upon the half of the circular track which meets the

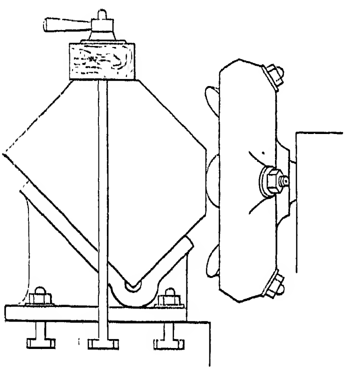
stone to just relieve the following half from contact with the surface produced by the first.

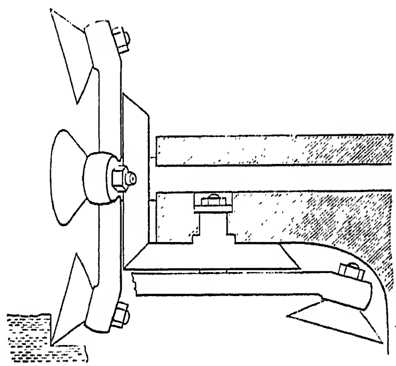
Similar machines to fig. 178 are also employed for dressing the flat faces of granite millstones up to 5 feet diameter. These are levelled in three breadths, each finished smooth by one traverse of the stone beneath the chuck which cuts in steps and removes a thickness of one inch from all over the surface; and Mr. Brunton informs the writer that, inclusive of mounting the stone on the table and shifting the chuck to its three positions along the slide, the one face of a 5 foot millstone is reduced smooth and level in one hour. The stone rotates in another machine that is used for dressing the one surface and the circular edge of large grindstones simultaneously. The rough gritstone placed upon a turntable something less than its diameter rotates at a moderate pace beneath the rapidly revolving chuck, which latter is shifted from point to point along the horizontal slide to surface the grindstone by two or three circular breadths from the circumference to the center; and one of the uprights of the machine carries a single cupped disc on a horizontal pivot mounted in a vertical slide, by which it is traversed to dress the edge with which it revolves by simple surface contact as in the disc stone turning lathes.

The vertical pressure of the chuck is unnecessary for dressing building stone, and in these Side dressing machines, the mandrel is horizontal and the chuck revolves vertically beyond the frame of the machine, as indicated in fig. 183, and the block on its travelling table passes in front of the track of the discs. One of the largest of these machines employed on the spot for dressing all the building stone for the Carlisle Citadel Railway Station, had an internal chuck 7 feet in diameter, driven at 70 to 80 revolutions per minute, and carried twelve 12 inch chilled iron discs. The proportion of the main bevel wheel to the pinions on the cutter spindles, all within the chuck, was as 12 to 1, so that the latter made from 840 to 960 revolutions per minute; the main wheel stood still, or at most received a moderate rotation to yet further accelerate the pace of the discs. The hollow mandrel carrying the chuck is mounted to run in bearings on the top of a massive headstock, and is provided with a power of endlong motion to advance the discs against the stone for depth of penetration;

the lower edge of the chuck runs in a pit in the masonry upon which the machine is built, and blocks of stone of any size up to about 6 feet thick by $3\frac{1}{2}$ feet wide by 9 feet long, mounted to overhang the side edge of the travelling table, are surfaced in one breadth by once passing in front of the chuck. The rate of production of this machine when used with one table only is 54 superficial feet per hour, but when used for surfacing quantities of slabs, such as paving flags, the machine is supplemented by tramways and numerous trolleys, which latter loaded and unloaded at a distance, are rolled on to the table in

FIGS. 183. 184.





continuous succession and the rate of production is then more than doubled.

For bevelling mullions, etc., the blocks of stone after being surfaced on all four faces are mounted on an angle bed, fig. 183, a strong iron casting bolted down to the table, the stone is held on the angle bed by long screws, their heads in an under cut groove in the table and their upper ends passing through a balk of timber above.

In another machine of this group for rebating building stone patented by Mr. F. Trier, two chucks are employed, their axes in the same plane but at right angles, driving one another and dressing the two faces of the rebate simultaneously. The two chucks are made precisely alike in all their dimensions, each in the form of a cross the four equal arms radiating from a central boss, and the thickened end of each arm is bored through from back to front with a plain hole to receive the

pivot of its disc; the pivot holes are inclined inwards to throw the track of the cutters outwards, and the pivots which are adjustable lengthwise to more or less project the discs are fixed within the holes by binding screws. The discs of cupped sheet steel revolve by surface contact only.

The diagram, fig. 184, shows the general arrangement of the acting portions. The one chuck which revolves vertically to dress the upright face of the rebate, has a toothed bevel wheel immediately behind it, the two fixed together on the projecting end of a long horizontal spindle, carried in bearings in a block which is traversed up and down by a screw and vertical slide in the uprights of the machine; the rear end of the spindle carries the driving pulleys. The second chuck, one arm and disc of which alone are shown in fig. 184, with its bevel wheel of equal dimensions to that of the first, revolves horizontally upon a vertical pivot or dead center fixed in the under side of the same block, and the pair of bevel wheels are keyed to gear so that the driven spindle drives the chuck on the fixed pivot with the arms of the one revolving chuck falling exactly centrally into the intervals between those of the other; and as the axes of the two chucks are on the same plane, provided the projections given to the equally sized discs are alike, the vertical and horizontal tracks of the cutters exactly meet in the internal corner of the rebate. The table has two movements, one continuous to traverse the stone lengthwise, and the other at right angles to it used intermittently after every such traverse to increase the breadth of the horizontal face of the rebate. The extent to which the block of stone is moved towards the vertical chuck, and that by which the two chucks are brought down on to the stone by the vertical slide of the machine, determine the relative widths of the two faces of the rebate, and these, therefore, may be alike or the one greater than the other as may be required.

SECT. IV.—GRINDING AND POLISHING SUPERFICIES IN STONE AND MARBLE BY MACHINERY.

Marble works of small and medium size are ground flat upon horizontal revolving laps after the same general method as that pursued by the lapidary, but with a proportionate

increase of size in the lap, which is supplied as usual with sand and water. The laps for marble works are made as circular plates of cast iron, from 6 to 20 feet diameter, and about 3 inches to 6 inches thick when new; they are mounted in various ways upon vertical spindles, with their upper sides or faces about 2 feet 6 inches above the ground. Across the face of the lap, or *sanding plate,* one or two strong square bars of wood faced with iron, called guide bars, are fixed so that their lower sides may just avoid touching the face of the lap, and their edges present perpendicular faces from 5 to 6 inches high, at right angles to the face of the lap. The guide bars serve as stops to prevent the work from being carried round by the lap, and also as gages to ensure the work being ground square. The piece of marble is laid flat upon the lap, with the face to be ground downwards and the side of the work in contact with the guide bar. Water is allowed to drip upon the plate from a cistern fixed above, and small quantities of sand are thrown on as required. During the progress of the work the workman leans upon the marble, the position of which he shifts occasionally to or from him to expose both the work and the lap to an equal amount of wear and prevent the formation of ridges, but which latter occur less with iron laps used for grinding large surfaces of marble, than when small objects are applied upon lead laps, as by the lapidary and mechanician.

The one side of the marble having been reduced to a flat surface, the work is turned over to grind the adjoining face, and the first face is held in contact with the perpendicular side of the guide bar, in order to present the second face of the work to the lap exactly at right angles to the first. When two pieces of similar size are to be ground each on the one face and two edges, as for the upright sides of a chimney-piece, the two pieces of marble are cemented together back to back with plaster of Paris, a process that is called *lining,* and the pair are ground as one piece on all four faces; in this case the flat sides are first ground parallel with each other, or of equal thickness on the two edges, and the latter are then ground square by placing the sides in contact with the guide bar.

When the lap is of moderate size, one guide bar only is employed, fixed across the diameter of the plate, which then allows of two workmen being employed on the opposite sides;

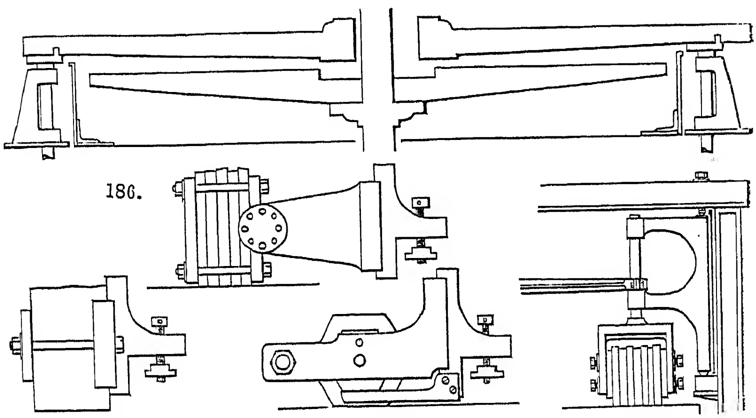
but large sanding plates sometimes have two or three bars placed at equal distances across the face, and four or six workmen may then be employed at the same time upon separate pieces of marble. Large sanding plates used for surface grinding only are frequently unprovided with guide bars, the workman then continuously moves the marble slab swinging it in circles upon the revolving plate from the edge towards its center. The larger sanding plates are also sometimes built up of two thicknesses for the convenience of repairs or replacement. In such case the thick iron plate previously described has its surface covered with a second of less substance, in the form of a number of sectors placed edge to edge and reaching from the circumference over rather more than one-third of the diameter towards the center; thus forming a central open space and a wide annular grinding surface around it. The sector-shaped plates are pierced with countersunk holes to contain the heads of the screws by which they are fixed down to the circular plate below; and the holes above the screw heads are sometimes left, or they are filled in with lead and antimony level with the general surface. In a sanding plate of this character patented in America by J. McEnerney, 1889, the sectors have bevelled edges and are fixed down slightly separated from one another, to leave radial spaces of from half to one inch wide between them. The plate revolves so that the obtuse angular edges of the sectors meet the work, and the intention of the narrow radial, sloping open spaces is to hold and more evenly distribute the sand.

The sand and water are continually thrown from the grinding surface of the laps by centrifugal force, and the large size of the work sometimes applied often prevents the use of a rim standing up above the level of the lap to catch the wet, as used by the lapidaries; but these large grinding plates, whenever possible, are surrounded by a circular casing standing about 9 inches away from their edge and about a foot above their surface. When not thus encompassed, every workman stands within a vertical trough or box about three feet high, without a back, which serves to protect him from the continuous shower of sand and water.

The larger iron sanding plates are cast considerably thicker towards their centers, from whence their under surfaces taper

to the circumference; and they are very generally mounted to revolve on the upper ends of their vertical spindles. When so mounted and notwithstanding their strengthened section, the flat upper grinding surface is found to sway or droop from the true horizontal plane and most towards the circumference; to overcome this they have to be weighted on the surface towards the center. Mr. Brindley says,—this droop is scarcely and not injuriously felt when the spindle is extended through the

FIGS. 185.



186. 187. 188. 189.

plate to run in centers or bearings above and below it; and also that there is no objection to this mode of mounting because, from its comparatively low rate of speed, the central portion of the sanding plate is practically not used, the work being executed as near the circumference as possible to secure the greater surface velocity. The surfaces of large slabs for want of better means, however, are sometimes of necessity ground upon the sanding plate, in which case the axis must be below to allow the slab to be traversed across the face of the plate by a man at either end; but these works are also far more accurate when executed in the machines described later in this section.

The sanding plate has also been provided with mechanical means for holding the work and for imitating the movements otherwise given to that by hand. A machine used in Belgium and patented by M. Jules Dejaife, 1885, partially shown in

section fig. 185, has the ordinary large sanding plate with the central portion recessed and unused, running at about two feet from the ground on a vertical spindle which extends through it above and below, and surrounded by a casing to catch the wet. Six strong vertical shafts mounted outside the casing and equidistantly from the axis and around the circumference of the sanding plate, terminate above in equal cranks made in the form of round flat plates with eccentric pins, and support and move a set of horizontal arms parallel with and transversely to and fro across the face of the revolving sanding plate; these vertical shafts being driven slowly, and simultaneously. The horizontal arms resemble the nave and spokes of a huge cartwheel, the nave formed as a deep open central ring to permit free movement about the vertical spindle, cast in the solid with opposite radiating girders of rectangular hollow section, flat planes on their upper surfaces parallel with the sanding plate and flat at their extremities below where they rest on the crank plates, and thickening thence to the central ring to increase their stability. The girders are grooved throughout their upper flat surfaces to receive the bolts by which the clamps for the work are fixed to them.

The clamps all consist of brackets fixed down on the radial arms and their overhanging vertical faces carry different arrangements to hold various forms of work; figs. 186—189 explain their general character. Those for grinding the one face of a block of stone fig. 187 are provided with a vertical slide against which the work is fixed by a parallel plate and bolts; the slide is free to descend the face of the bracket and the weight of the single block, or that of several pieces which may be gripped face to face, is usually sufficient to give the pressure, otherwise additional weight is placed on the top of the work. The clamp, fig. 186, is employed to grind the two opposite edges of the work parallel with one another. In this the work is removed from contact with the face of the slide, and is held between two parallel plates, one of which is mounted to turn on centers placed at the ends of arms cast in the solid with the vertical descending slide; circular division plates with holes, keyed on the spindle of the pivotted plate, and pins passing through into the arms, secure the correct adjustment when the block is turned over to grind opposite

sides, or to hold it, or a series of slabs clamped together, to grind bevelled edges. Flat pieces of marble for tesselated pavements and other works have their adjacent sides ground to equal lengths and angles in the clamp, fig. 188. The two arms of this clamp are connected transversely at their extremities to form an oblong frame, and are pierced at about the center of their length the one with a plain and the other with a screwed hole. The several pieces of marble previously ground flat and parallel on their surfaces, when *lined* or slightly cemented together face to face with thin plaster of Paris, are held between two square, hexagon or octagon gage plates of less dimensions than the area of the finished work, cemented to the ends of the collection in the same manner. One of these gage plates has a central cylindrical pivot fitting the plain hole in the one arm, and the other a central hollow center to receive the blunt point of a center screw in the opposite hole in the other arm; and the work and gage plates are held fast during the grinding by the pressure of the center screw secured by lock nuts. With the pressure relieved the work is turned partially round and refixed to grind adjacent sides, their angular truth secured by holes in the gage plates and pins passed into them through the arms of the descending slide; equality of width between each pair of sides for a regular figure, and of dimensions for grinding one series of pieces after another, is attained by adjustable arms fixed on the bracket which arrest the descent of the slide so soon as the under edges of the gage plates arrive in contact upon them.

A different and effective arrangement is shown by fig. 189, in which strong uprights planted around the circumference of the sanding plate are connected in pairs by transverse girders and carry brackets which swing on centers above and below. The clamps for various forms of work, of similar character to those just described, are attached to the lower ends of round shafts which are free to descend in the horizontal ends of the brackets, the weight of the clamp and work gives the pressure, and the whole is swung to and fro partially across the surface of the revolving sanding plate by horizontal rods jointed on the brackets and moved by eccentrics.

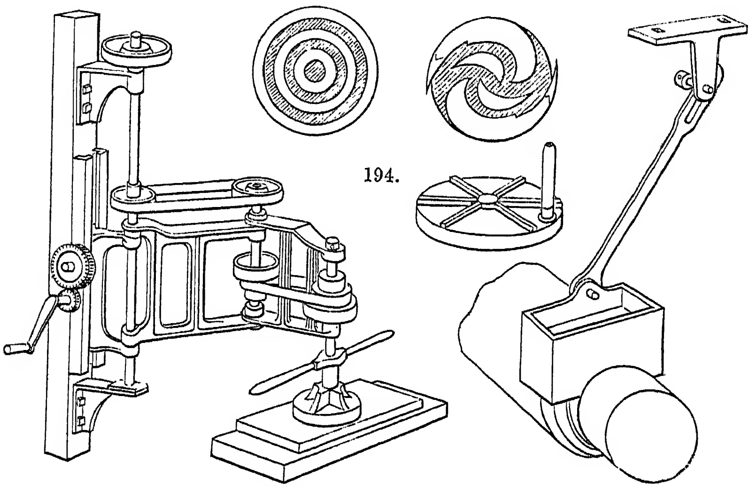
The stones used for lithography require grinding truly flat on both faces, and exactly parallel, especially for the larger,

to avoid risk of fracture by the pressure in printing. The smaller stones are usually ground by hand lying on a bench with the *levigator* fed with sand and water, their truth and parallelism secured under constant testing with the callipers and straight edge. The levigator, fig. 194, is a circular cast iron plate, 2 to 3 inches thick, by 12 to 14 inches diameter, ribbed above to maintain its stiffness as its under surface wears, with a vertical pin towards its circumference in a wooden sheath forming a kind of winch handle. This lies on the stone, its weight giving the pressure; the operator grasps the handle in one hand, and continually swings the plate round and round upon this pivot whilst he simultaneously traverses the tool in parallel paths across and across the stone in all directions, always allowing about a third of its diameter to pass beyond the edges at the end of every traverse; a little water drips on the stone and moderate supplies of wet sand are thrown on from time to time with the other hand, and the bench is surrounded with a wood casing to catch the wet that drips from the stone. The face to be printed from is subsequently smoothed, plentifully wetted with water, first with the flat face of a lump of pumice stone and then with one of water of ayr stone 6 or 8 inches long, grasped in both hands and rubbed in parallel strokes in all directions across the surface, under continual testing with the straight edge.

Large stones are ground in machines upon a horizontal table slowly reciprocated below a circular cast iron disc from 4 to 6 feet in diameter, in rapid revolution upon the lower end of a vertical spindle which is gradually lowered by an arrangement very similar to that shown by fig. 202, so that a part or the whole weight of the sanding plate may rest on the stone as the grinding proceeds; the diameter of the disc always exceeds the width of the stone, and the lengthwise reciprocation of the latter causes the corners to travel well under it, and small streams of sand and water drip on the stone to either side of the revolving plate. For a new stone, already cut fairly parallel, one face is first roughly corrected, if necessary, for it to *bed* without rocking on the table; the upper face is then ground, the high points being gradually reduced by the lowering of the grinding plate until a flat surface is obtained, the stone is then turned over and the second face ground flat and

parallel with the first. After this the working surface is smoothed with the levigator and finished with the pumice and water of ayr stones. Stones in daily use have the drawings removed from them and their surfaces reinstated to receive others with the hand tools, and are only reground in the machine should they be found to have lost parallelism.

FIGS. 190. 191. 192. 193.



194.

Pieces of stone and marble of moderate dimensions are sometimes ground flat, smoothed and polished under the revolving hand tools, figs. 111, 112, driven by the flexible shafts described page 282, or by the bracket driving apparatus fig. 190; but the emery disc is exchanged for a *sanding plate*, a flat round cast iron plate about 12 or 14 inches diameter fed with sand and water, or for polishing, for discs of wood covered with felt and fed with the polishing powders. The work lies on the rubbing bed or on a table of convenient height for the workman to move the tool about in small circles, alternated by straight traverses, in all directions and to exert pressure upon it. Nearly cylindrical pieces of iron, fig. 113, fed with sand and water and driven by the shaft, are also used for smoothing and finishing flutes and cavettos in mouldings previously roughed out in the stone by hand.

These small revolving sanding plates, little used in this coun-

try, find more favour on the Continent and in America. The flat under surface of the circular iron plate is also sometimes recessed by a series of deep grooves, fig. 191, to retain the sand, the annular portions left between performing the grinding, and the sand and water is supplied through holes made in the upper surface or cover. A late variety patented by Mr. Geo. Barney Eckhardt, of Toledo, Ohio, U.S.A., is formed of flat crescent shaped pieces of cast iron attached to a circular plate fig. 192, which by their revolution gather up and redistribute the sand upon the work under the grinder. The moist sand which is swept in at the openings at the periphery, travels along between the crescents to the center of the plate, its movement assisted by its forcible contact with the projections formed on the inner edges of the external crescents, which deflect the sand on to the outer edges of the central pair of crescents; the two thin external points wear blunt and are renewable.

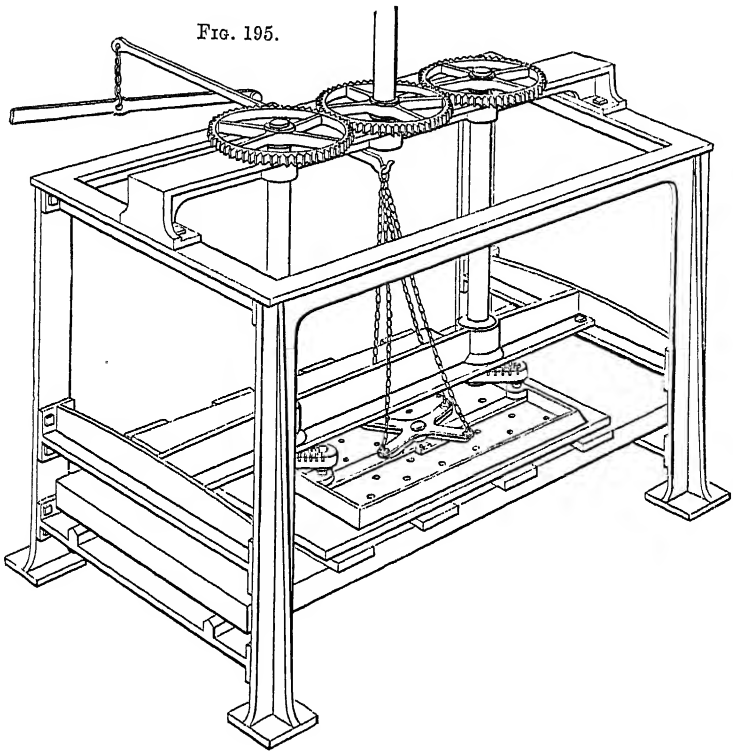
The Universal Arm bracket driving apparatus employed by Mr. Wright, Montpellier, Vermont, U.S.A., fig. 190, is free to descend the vertical shaft from which the motion is given to the spindle of the sanding plate, which latter may be traversed about in all directions upon the work within the limits of the range of the apparatus. The weight of the arm gives the pressure for the grinding, and the arm is raised by a rack and pinion whilst the work is adjusted beneath the grinding plate.

In similar French machines the light open framing of the horizontal bracket is replaced by a strong solid tapering arm, which is hinged at its larger end to the top of a massive cast iron upright, has a second hinge at the middle of its length and carries the spindle with the grinding disc at its lesser extremity. Bands convey the motion, in like manner to fig. 190, from pulleys running upon the pins of the two hinges to one upon the spindle of the grinder; the latter traverses vertically through its pulley by means of a key way and feather, and the pressure is given by a weighted lever attached to the upper surface of the arm and bearing by a collar on the top end of the grinder spindle.

Large slabs of marble and stone are very accurately ground in a machine long since patented by Mr. Tulloch, called a

grinding bed. In this machine, represented in fig. 195, the slab to be ground is placed horizontally upon a moving bed, and the grinding is effected with sand and water by means of a large flat plate of iron resting upon the surface of the slab. The two surfaces are traversed over each other with a compound motion, partly eccentric and partly rectilinear, so as

FIG. 195.



continually to change their relative positions. The machine consists of a frame about 9 feet long, 6 feet wide, and 8 feet high; about 2 feet from the ground is mounted a platform, that is very slowly reciprocated horizontally for a distance of from 1 to 2 feet, according to the size of the slab, by means of a rack and pinion placed beneath, and worked alternately in both directions.

Above the platform are fixed vertically two revolving shafts, having at their upper extremities horizontal toothed wheels of equal diameter which are driven by means of a central toothed

wheel keyed on the driving shaft. The two vertical shafts are thus made to revolve at equal velocity or turn for turn, and to their lower ends are attached two equal cranks placed parallel with each other, the extremities of which, therefore, describe equal circles in the same direction. The iron grinding plate or runner is connected to these cranks by pivots fitting two sockets placed upon the central line of the plate and the cranks are made with radial grooves so that the pivots can be fixed by wedges at any distance from their centers. When the machine is put in motion the grinding plate is thus swung round bodily in a horizontal circle of the same diameter as the throw of the cranks, which is usually about 12 inches, and consequently every portion of the surface of the grinding plate would describe a circle upon the surface of the slab being ground if the latter were stationary. But by the slow rectilinear movement of the platform the slab is continually shifted beneath the plate so as to place the circles, or rather the cycloids, in a different position, and it is only after many revolutions of the cranks that the same points of the surfaces of the grinding plate and slab are a second time brought in contact.

The grinding plate is raised for the admission of the slab by means of four chains suspended from a double lever, and attached to the arms of a cross secured to the center of the upper surface of the plate, which is thus lifted almost like a scale pan. For slabs that are much thicker or thinner than usual, the principal adjustment is obtained by the removal or addition of separate beds or loose boards, laid upon the platform to support the slab at the proper height. Slabs that are too large to be worked over the whole surface at the one operation, are shifted once or twice during the grinding, to expose the surface equally to the action of the grinding plate; and the necessary pressure is given by the weight of the horizontal plate, which is supported almost entirely by the work, as the pivots of the cranks merely enter the sockets, and allow the plate to descend when left to itself. For delicate works a counterpoise weight is attached to the double lever so as to regulate or diminish the pressure.

The sand and water is applied to the grinding surfaces in much the same manner as in the iron runners used by hand previously described. The grinding plate is made on the

upper side with a raised rim like a tray, and the bottom of the tray is perforated with numerous holes about $1\frac{1}{2}$ inch diameter arranged at equal distances apart. The sand and water is thrown into the tray at intervals in small quantities, and runs through the holes and between the surfaces of the slab and grinding plate, which are thus uniformly supplied with the feed that ultimately makes its escape around the edges of the grinding plate. Various qualities of sand may be employed according to the perfection of surface required, and very flat surfaces are produced by this machine. The *grounding* or smoothing of the best works is effected with a succession of fine emeries, with which the surfaces may be made very smooth, and almost polished; but from motives of economy, the grounding of ordinary works is more frequently completed by hand, with grit stones and snake stone before the work is finally polished on another machine, fig. 200.

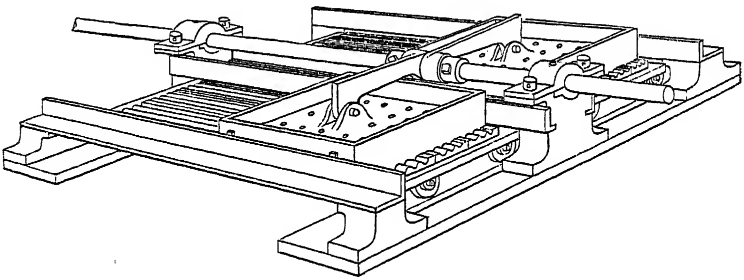
The machines for producing rectilinear mouldings in stone and marble differ in their character with that of the mouldings themselves. When the latter are shallow, the work is stationary and they are ground out with reciprocating counterpart rubbers, a method founded on the hand processes already described, but when deep they are more generally ground out with counterpart revolving grinders, the work reciprocating, the machine following the general character of the ripping bed.

The machine, fig. 196, patented by Sir James Jelf, so far back as 1822, is still met with, and is also interesting as the successful type of the reciprocating rubber machines used for the production of the shallow rectilinear mouldings on pilasters, the jambs of chimney pieces and similar works required in large quantities.

The base of fig. 196 has two headstocks which carry a long cylindrical shaft that is reciprocated horizontally from the one end. Two heavy rectangular cast iron rubber plates below, one to either side of the shaft, are propelled by the latter, to which they are connected each by an arm jointed to the center of their upper surface and between collars fixed on the shaft, and either rubber may, therefore, be lifted independently from the work; and adjustable projecting pieces on the outer side

edges of the rubbers travel in contact with true guide bars, mounted against the central headstocks and at the sides of the base plates, to ensure uniform parallel motion. The work lies clamped or cemented on two stationary tables beneath, and the weight of the rubbers usually suffices for the pressure for grinding out the mouldings; if not, more is given by weights placed across the margins of the rubbers, which latter stand up all round them as a rim to form deep trays to contain the sand and water, which finds its way to the work

Fig. 196.



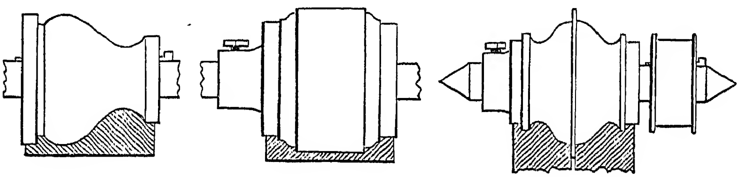
through numerous holes pierced in the rubbers. The under or grinding surface of the rubber is grooved from end to end with several counterparts of the flutes or mouldings to be produced on the marble, which may be in wide slabs to be subsequently divided into slips, or several pieces of the correct width of the finished work fixed edge to edge on the tables. The latter are also capable of a small traverse at right angles to the motion of the horizontal shaft to adjust the position of the work beneath the rubbers, after which the tables are fixed during the grinding; the mouldings usually extend throughout the length of the work, but the extent of the stroke of the reciprocating shaft and rubbers is curtailed for mouldings that stop short of it.

The machine for working rectilinear mouldings with revolving grinders, called the *moulding bed*, follows the construction of fig. 157. The thin saw blades are replaced by cylindrical pieces of cast iron turned to the counterpart of the mouldings to be ground, which can be fixed at any position along the spindle separated by collars in the same manner as the saws;

and the bearings of the spindle can be adjusted vertically to the proper height to suit the thickness of the marble. Indeed the ordinary ripping bed, when the spindle is provided with vertical adjustment, is used for working mouldings on large works; but a great proportion of moulded work is upon slips of marble only a few inches wide, and for these it is more usual to employ a narrower machine.

The forms of some of the grinders are shown in figs. 197 to 199; the outline represents the grinder, and the shaded part beneath, the entire compound moulding that would be produced

FIGS. 197. 198. 199.



on the work. A separate grinder is required for every different moulding and consequently a large number have to be provided to meet the demand for variety. They are all pierced with a central hole fitted to the spindle of the machine in which they are to be employed, and are secured either by a wedge or a side screw, so that they admit of being readily exchanged when a different form of moulding is required.

The grinder of suitable form having been selected and fixed on the spindle of the machine, the slip of marble is cemented with plaster of Paris upon the bed, and the frame carrying the spindle is adjusted by the screws beneath to the proper position to allow the grinders to penetrate the marble to the required depth for the production of the moulding. As in the ripping bed, the grinder is made to revolve so as to cut upwards towards the surface, and the attendant keeps a small heap of moist sand constantly in contact with its face. The weight attached to the sliding bed by a line passing over a pulley keeps the work constantly advancing in a straight line towards the grinder as fast as it is cut, and the work finally presents a compound rectilinear moulding of exactly the counterpart form of the grinder. Mouldings on the edges of narrow slips are sometimes wrought in pairs, as in fig. 199

the two pieces being cemented together sideways as one block, which is placed edgeways upon the machine.

A third method is followed for roughing out and preparing rectilinear mouldings in sand and building stones, which are afterwards finished by counterpart scrapers or rubbers. In some machines the block of stone is carried along on a travelling bed to pass under a horizontal revolving block or cylinder armed with a series of short strong steel blades, arranged either in a straight line along it or spirally around it; in others a similar spindle is mounted to stand vertically and the cutters operate on the side of the block. The faces of the cutters which meet the work stand as tangents to a small circle, and their stems are adjustable as to projection from the mortises in which they are held by set screws; the spindles of the horizontal cylinders are lowered towards the work to give the depth of cut, but the vertical spindles revolve in fixed positions and a lateral advance towards them is then given to the work. Other machines closely copy the ordinary planing machine for metal and have single or several fixed cutters which are gradually lowered for depth of cut upon the stone traversing beneath them; the disc cutter when used in this manner is mounted in a hinged holder, fig. 166, that it may stand vertically when cutting and tilt up during the reverse traverse of the stone. The whole of this group are either chipping or scraping and not grinding machines and, more especially those with flat revolving cutters, are rather liable to *pluck* or drag out small portions from the surfaces of the mouldings they produce even in the softest stones. This evil is greatly due to the differing radii of the cutters for the deep and shallow portions of the mouldings and the consequent different surface velocities at which their edges revolve. For which reason, and also because a wide cutter for a flat, or a curved one that would embrace the whole of a large curved member of a moulding, take too great a hold and drag upon the stone, wide cutters are notched at intervals upon their edges, or several narrow ones are substituted a little separated from one another; the small ridges left by the notches or intervals break away as the work progresses and their residue is removed when the moulding is finally cleaned up to smooth finish, which last operation is effected with straight rubbers or

sometimes with revolving cutters or scrapers of the profile of the moulding.

The small steel disc cutters are used in the machines for rectilinear mouldings at the York Road Station Works; one of which machines has a strong vertical spindle standing free as to its upper end and supported and driven below by bevel gear, close against the side of the travelling table. The disc cutters are mounted in flat iron plates, fig. 168, with central holes fitting the spindle and of different radii; there are two cutters at each end of the plate held in place by a taper washer and binding screw, with the excellent feature that the pair at one end of the plate is advanced a little more than that at the other, and of each pair one disc also projects a little more than its fellow, hence the work to be done, or the depth of the groove cut by each plate is divided among four cutters and being thus lessened for each is also much improved in quality. A number of these radial plates are threaded upon and arranged for their cutters to stand spirally around the vertical spindle, the most advanced disc in each plate just touching a template of the moulding temporarily mounted parallel with the spindle, and the whole are then clamped together as a mass against a collar below on the spindle by a screw and nut upon its upper free end. The spiral arrangement is necessary because the diameters of the disc cutters is greater than the thickness of the plates, but it also has the advantage that the work done by every set of four cutters overlaps that performed by the cutters in the plates above and below it. Thus a wide curved or flat member of the moulding is cut as a number of narrow grooves in close juxtaposition, and the ridges left between the grooves are not only smaller than before but are of a pyramidal section and less liable to pluck. The work done by the disc cutters is a fair approach to the required moulding, and that is completed and the ridges are scraped down by flat blades of the precise profile of the moulding revolving on the spindle, whilst work which requires a further degree of finish is finally treated with rubbers. The main table which traverses the work past the cutters also carries a transverse movement sometimes used to advance the stone laterally towards the cutter spindle for depth of cut; or the block may be swung round on the main table to present its

sides one after the other to cut the mouldings on square pedestals and other polygons to mitre at the corners; or the table may be tilted up to place a moulding at a vertical angle to the axis of the block.

Emery wheel or cylinder machines have also been frequently tried for grinding out mouldings and for smoothing flat surfaces on stone. This attempts to reverse the ordinary practice, viz., the use of a hard rubber of metal or stone for its permanence of truth, and sand or some other abrasive powder between it and the stone to do the actual cutting,—the emery wheel or cylinder, on the other hand, has to supply both particulars and its rapid loss of form from its friable nature interferes with its successful application to these purposes on stone.

Circular mouldings in marble, such as those upon a column, are very generally wrought by turning in the lathe with a bar of steel drawn down at each end to a taper point, used and kept in working condition in the manner described page 167, Vol. I.; and they are subsequently smoothed with sand and water and polished with the various polishing powders applied on rubbers as already described. Large mouldings on marble and all on granite and the harder stones are turned by other tools applied in the following sequence. The material roughly chipped to an approach to the circular form before it is mounted in the lathe, first, has the moulding turned to approximate shape with the revolving disc tools previously described and again referred to a few lines later in this section. The disc tool applied in the sliderest may be clamped therein with its stem at any horizontal angle, and advanced for depth of cut or moved for extent of traverse upon the work by the one or the other of the two slides of the sliderest, so that by these changes and a little management the edge of the revolving disc may be made to follow and rough out the moulding very nearly to its form, and its flats and fillets to greater accuracy. The steel point is then sometimes used to follow the disc tool on marble to complete the curvatures, especially for quirks or deep incisions.

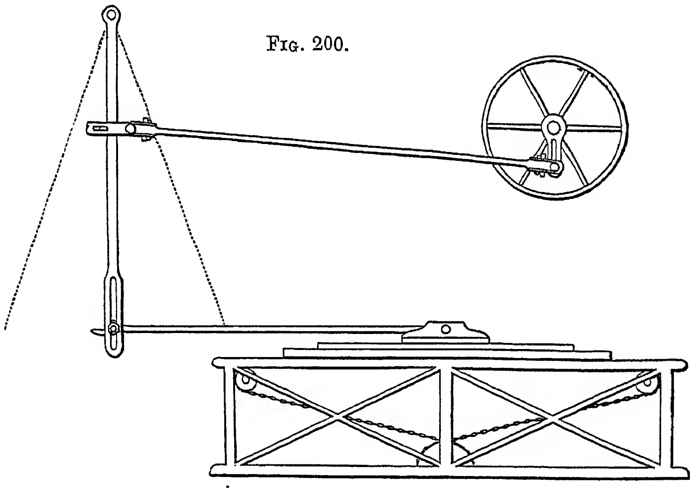
The material when of granite or the harder stones, so far prepared, being then everywhere circular, the disc tool is exchanged for one of the carbonate diamond tools, figs. 390–392, applied and manipulated by hand or in the sliderest after the

same general manner to complete the moulding. The diamond tool plentifully and unceasingly supplied with water, is traversed along the faces of the flats and fillets, and when these are adjacent into the sharp internal angles, leaving these portions smooth and to the finished size. The curved members of the moulding are completed seriatim by turning them away in a series of fine grooves made in close juxtaposition, and then reducing the little ridges between in a similar manner, the depths of the grooves being gradually lessened as the completion of the form is approached. The circular mouldings are finally smoothed and polished with counterpart and other rubbers, fed with the grinding and polishing powders in the order already noted. For the larger mouldings and especially for those on granite, the grinding and smoothing rubber takes the form of a heavy cast iron block, fig. 193, its working surface a counterpart arc of the moulding, usually jointed to the end of a long rod which is pivotted somewhere above and to the side of the revolving work. The rubber often itself weighted, is pierced with many vertical holes and surrounded by a rim above to contain and transmit the sand and water or other grinding medium to the work.

The above methods are employed to produce the forms and the mouldings of bowls, vases and tazze in marble, granite, porphyry, and other valuable and intractable stones. Great practical difficulties are overcome in this class of stone turning, and it may be mentioned that Mr. William Banks gained the Freedom and the Silver medal of the Turners' Company in the Competition of 1885, for several beautiful specimens of his workmanship among which were some porphyry tazze with bowls twelve inches diameter and but the one-eighth of an inch in thickness, standing upon stems turned with them in the solid. The turning of this high class work when carried so far as possible with the sliderest tools still leaves very much to be completed with the hand carbonate tool; the manipulation of the latter requires considerable dexterity, the more because the round stem of the tool has to be frequently partially rolled over on its support to bring the angle of the carbonate into its best abrading position on the hard stone, hence, it is difficult to hold the tool with sufficient firmness and yet to apply it with the necessary delicacy of touch.

Bosses and other small flat circular mouldings, decorations sometimes planted on or incised in rectilinear work, are ground to their forms by machinery of which the cutting portions follow the general character of those described figs. 170-173. The grinders are made of cast iron turned to the counterpart forms of the mouldings, as shown in section fig. 170, and are screwed to the lower end of the upright revolving spindle in the same manner as the circular cutters; they are kept well supplied with moist sand and the grinding is continued until the circular pattern is entirely developed, the work is afterwards polished in the lathe as mentioned in the Catalogue, MARBLE, article 2.

FIG. 200.



The polishing of rectilinear works in marble by machinery closely resembles the polishing of flat slabs by hand, previously described, the chief difference being, that for large slabs, from 2 to 6 rubbers or blocks are employed, and are reciprocated by the machine instead of by hand. The slab of marble is laid upon a flat bench or table about 12 feet long and 6 feet wide, and at a moderate height above the bench is fixed a crank driven by the engine, a connecting rod from which leads to an iron swing frame, working as a pendulum placed 2 or 3 feet from the end of the machine. Fig. 200 represents the side view of the polishing bed; the swing frame consists simply of two rods moving upon centers above, and carrying near

their lower extremities a horizontal bar extending the entire width of the bench; to this bar as many separate iron rods are attached as there are rubbers to be employed at one time, and every rod is jointed to its own rubber, which for flat surfaces consists of a block of wood about 2 feet long and 6 inches wide, covered with thick felt, as explained in the Catalogue Rubbers, articles 3 and 4. The attachments of the connecting rods to the crank and pendulum are all capable of adjustment, so that the length of stroke can be readily changed to suit the size of the work in course of being polished, but generally the stroke is about 3 feet long.

The rubbers are used with the succession of powders mentioned in the Catalogue, Marble, articles 1 and 2, and the weight of the blocks and rods supply the pressure. Several narrow rubbers are used instead of one wide one, in order to allow each to adapt itself readily to any trifling irregularities in the surface of the slab. The rubbers are shifted across the width of the slab, by sliding their rods to other positions on the horizontal bar of the pendulum frame, and the platform of the machine is traversed endways by a chain and drum, or a rack and pinion, to expose the work equally to their action.

Rectilinear mouldings are polished in the same manner, except that elastic rubbers are employed. These are made of coarse cloth, like sacking, generally old sugar bags are used for the purpose; they are cut into strips about six inches wide, folded lengthways and nailed through the middle of the fold close together to a block of wood, so as to present when complete a surface 8 or 9 inches wide, composed of the edges of the cloth, the loose filaments of which penetrate into the angles of the mouldings. For polishing the edges of narrow works in marble several pieces are fixed close together edgeways in a wooden trough, and they are all polished at the same time.

CHAPTER VI.

THE PRODUCTION OF PLANE SURFACES IN GLASS.

SECT. I.—GRINDING AND POLISHING PLATE AND SHEET GLASS.

The grinding and polishing of plate glass by machinery is perhaps the largest example of the production of plane surfaces by abrasion; the following is a brief outline of the different modes of procedure.

In the manufacture of plate glass the materials are first fused in melting pots made of Stourbridge clay, which measure from 30 to 40 inches diameter and 3 to 4 feet high. The pots are made in the form of a truncated cone, being rather smaller at the bottom than the top, and are capable of containing a sufficient quantity of the melted glass to form four or five plates of the largest size. After the materials have been thoroughly fused together, a sufficient quantity of the melted glass to form a single plate, is removed by iron ladles from the large melting pot to smaller pots called *cuvettes*, which have been previously heated in another furnace. The glass now in a pasty condition is placed in the pots while they are in the furnace, which is then closed up and kept at a considerable heat for some hours, until all the air bubbles have been expelled and the glass is sufficiently fluid to be poured.

The pot is then removed from the furnace and carried on a truck to an iron table or bench, having a flat surface about 20 feet long and 12 feet wide, with two bars of iron of equal thickness to the desired plate laid upon the face of the table near the edges. The fluid glass is poured on the table and spread with iron or copper tools; an iron roller about 15 inches diameter, equal in length to the width of the table, and weighing about 30 cwt. is then rested upon the two iron bars and traversed over the face of the glass to roll it out like dough to a uniform thickness. To insure the rotation of the roller in a straight line along the plate, it is provided at each end with

toothed wheels that work in corresponding racks fixed on the sides of the iron table, and the roller is drawn along the latter by means of two chains coiled around the ends of the cylinder and worked by a windlass.

When the glass has been rolled flat, the cylinder is received at the end of the table upon two arms counterpoised by means of levers placed beneath, so as to allow of the heavy roller being raised or lowered by two or three men. The plate still red hot and yielding is slid from the table upon the flat surface of a carriage which is wheeled to the annealing oven, upon the bed of which the plate is pushed and allowed to remain for several hours to gradually cool. The plates when cold are examined as to their condition, and those which present defects or irregularities in the surface that it would be tedious to grind out, are cut with the diamond into smaller pieces, but the nearly perfect plates are kept as near their full size as possible, and merely squared on the edges.

The plates of glass now measure from half to one inch thick, and the surface is full of small irregularities presenting a mottled appearance, the roughest side being generally that which was placed downwards upon the bed of the annealing oven and has copied all the irregularities of the bricks of which the bed of the oven is formed. The side of the glass that was uppermost in the oven is comparatively smooth and bright from the action of the fire, although in many cases this surface is not so nearly flat as the lower. The plates have therefore to be ground flat and polished on both sides; formerly this was effected entirely by hand, but the rough grinding with coarse sand, the smoothing with finer sand and emery, and the polishing with crocus, are now almost always done by machinery, and hand labour is only sometimes resorted to for the intermediate process of smoothing with fine emery.

The grinding and polishing machines differ rather widely in their construction. In some the plate glass is cemented down on a fixed bed and is ground with sand and water by means of other pieces of the glass cemented to the under sides of plane surfaces called *runners*, which, themselves rotating, are swung round in a circular path upon it. In other machines, the glass is fixed to the surface of a plane circular table of large diameter, which revolves horizontally on the top end of a vertical

spindle after the manner of the sanding plate, fig. 185, and the runner covered with pieces of glass or more generally with bars of cast iron and fed with sand or emery, rests on and rotates by its surface contact with the glass on the revolving table. For the polishing, the glass is detached and remounted on a slowly reciprocating rectangular table under a series of numerous flat, felt-covered *rubbers* fed with the polishing powders, which travel to and fro at right angles to the direction of motion of the table. In the most modern practice the glass remains throughout on the circular revolving table, from which the runner is removed after the grinding and smoothing, and replaced by other apparatus for the polishing; this system economises time and avoids risks of breakages, but requires extreme care to remove all trace of the coarser powders first used, as a single grain of the sand or emery finding its way on to the rubbers scratches the polished glass and prolongs and will sometimes necessitate a recommencement of the polishing process.

The grinding machines formerly exclusively employed for the largest plate glass are arranged in pairs along the grinding room; every pair of machines is driven by one central beam, and consists of two benches of stone about 15 feet long, 8 feet wide, and 18 inches high, placed some 10 feet asunder; upon each of these benches one or more plates of glass are embedded in plaster of Paris, close together and quite level. Other plates of glass are cemented upon the lower faces of two swing tables or runners, which are traversed over the fixed beds by a horizontal beam about 30 feet long; the machinery for driving the beam is fixed in a frame about 6 feet square and 18 inches high, placed between the two grinding benches. A horizontal shaft fixed underground extends throughout the length of the grinding room between the lines of benches, and the motion from the shaft is communicated to every pair of machines, by a pair of bevel wheels leading to a central crank that revolves horizontally and has a radius of about 2 feet; the arm of the crank is attached by a pivot to the center of the horizontal beam. Four other cranks of the same radius are placed parallel with the central driving crank, one at each corner of the square frame, and serve to guide the traverse of the horizontal beam, which is thus swung in a circle of four

feet diameter in a manner somewhat similar to the grinding bed for marble, fig. 195. The beam is supported at various parts of its length by chains suspended from the roof of the building, which allow of its traverse, and serve for raising it by means of levers for the removal of the work.

Near each end of the beam is attached, with the power of adjustment for position, a small sliding frame carrying bearings for the reception of the central pivot of the swing table or runner, which consists of a strong frame of wood covered with boards and measuring 8 feet long and 6 feet wide, placed face downwards upon the bench; a central pivot stands up from the back of the runner and enters the bearing fixed on the horizontal beam, which thus communicates a circular swinging motion to the center of the runner exactly the same as that of the driving crank; and the runner being free to revolve upon its pivot, acquires a continual rotation around its own axis. By the combination of the two movements the relative position of the fixed bench and runner are continually changing; this tends to the mutual correction of the two surfaces of the glass and greatly assists the equal distribution of the sand and water used in grinding. The horizontal beam makes about fifty circulating strokes in a minute, and the runners revolve upon their own axes about once to every five or six strokes. The position of the runners upon the driving beam is shifted once or twice during the grinding, to distribute the action as uniformly as possible over the entire surfaces of the glass plates.

The largest plates of glass are nearly equal in size to the fixed bench, and these are embedded singly upon it with the more irregular sides upwards; but more generally plates of medium and small size are ground together; they are selected of uniform thickness and arranged close together upon the bench, with the largest plates in the middle and the smallest at the ends. The runner is covered by one or two plates at most, as small pieces would be liable to be thrown off by the centrifugal force. All the irregularities of the surfaces are first ground out with sharp river sand, that has been washed and sifted into two sizes; the sand and water are thrown on by hand occasionally, and when the plates have been ground quite flat, the finer sand is employed, followed by emery of

two finer sizes, applied in succession, in order to remove the scratches made by the coarser powders. The plates of glass are thoroughly washed between every change of grinding powder, and when the one side of the glass has been ground with the finer sizes in succession, the plates are inverted, and the same routine is followed on the second sides.

The grinding machines do not however admit of being employed with very fine emery, as the close approximation of large surfaces travelling over each other at a considerable velocity, causes so much friction that it would be liable to tear the surface of the glass and, consequently, as the plates become sufficiently smooth to require the application of fine emeries, the velocity and pressure are proportionally reduced, and a greater degree of care and management is required; the final smoothing of plate glass, therefore, is frequently effected by hand.

The plates are smoothed upon stone benches of suitable size, about 2 feet high, made very flat upon their surfaces, and covered with wet canvas. One large plate nearly equal to the size of the bench, and two or three plates of about half the size, are usually given out as a set of work. The large plate is laid upon the wet canvas which serves to hold it firmly, emery and water are spread over the surface, and one of the small plates is used as a grinder or runner. If the plates be large, a few flat lead weights of about 14 lbs. each are laid near the middle of the runner, to distribute the pressure uniformly, and the runner is traversed over the lower plate with a swinging stroke backwards and forwards, so as to describe nearly a semicircle around its center, which is at the same time shifted a few inches during the stroke. Every stroke follows a slightly different path from its predecessor, and the runner is also gradually twisted round as the smoothing proceeds. The combination of these movements serves to expose every part of the surfaces of the bed plate and runner to an equal amount of grinding, and also to distribute the emery very uniformly. Small plates are smoothed by girls, and large plates which require greater dexterity and a proportionate increase in the amount of traverse, by two women, who stand on opposite sides of the bench, and placing their outstretched hands flat upon the runner swing it with a stroke

of five or six feet. The employment appears most masculine, but it is found that the smoothing is upon the whole executed better by women than men, as only a moderate force is required and from the greater delicacy of touch possessed by females, they more readily appreciate when any particles of grit have become accidentally mixed with the emery.

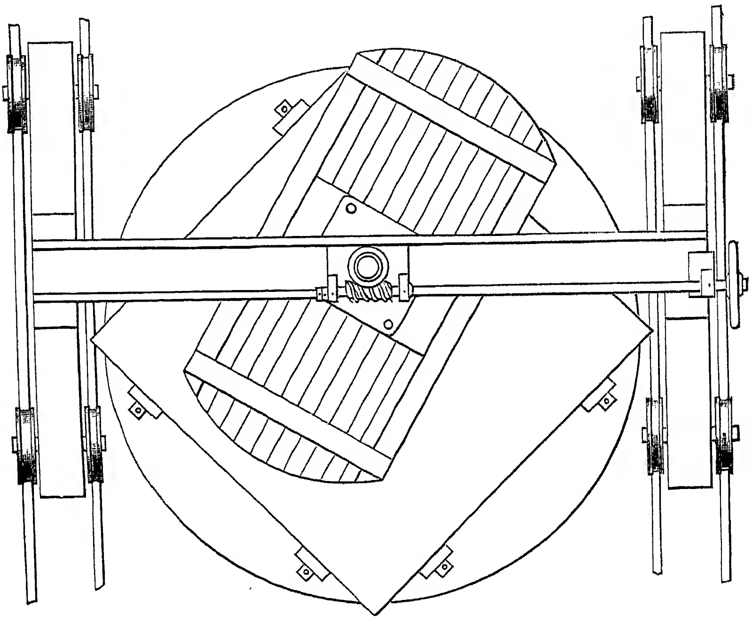
About six sizes of carefully washed emery are used in the smoothing, and between every size, the plates, canvas, bench and hands are thoroughly washed, perfect cleanliness in the clothing is also quite essential, as a particle of coarse grit would make a scratch that would require the smoothing of the plates to be recommenced. The fine emery last employed gives a very smooth and partly polished surface, which is completed with the machines next described.

The ordinary rectilinear polishing machine has a bed about 20 feet long by 10 or 12 feet wide, that is mounted upon rollers and slowly traversed sideways, a space of 4 feet to and fro, by means of a rack and pinion beneath. A few inches above the bed two beams or carriages are reciprocated longitudinally, each about 25 feet long and 12 inches wide, and consisting of two cast iron side plates connected together at intervals and supported at each end upon two small wheels, that run upon a short railway beyond the ends of the traversing table. The carriages are placed four feet asunder, and reciprocated about two feet by means of two cranks fixed opposite to each other on the same axis, so that the beams work in opposite directions, the one advancing as the other recedes.

The plates of glass are embedded close together with their surfaces quite level, upon detached platforms that are afterwards fixed upon the traversing bed, and the polishing is effected with a series of rubbers, placed one foot asunder and measuring 8 by 6 inches, covered with thick felt, attached to the reciprocating carriages, which drag the rubbers backwards and forwards over the surface of the glass, while the latter is traversed beneath them a space equal to the distance between the two lines of rubbers, to expose all parts of the glass equally to their action. Every rubber is separately attached to one of the two carriages, to allow it to ply uniformly to the surface of the glass, this is effected as follows; between the two side plates of the beam fixed near the top and bottom edges

there are two cross pieces having square holes, through which slides vertically a square bar, the lower end of which projects about two inches below the beam, and is cylindrical and hemispherical. The rubber is detached, with a central cavity at the back to fit the end of the upright bar, which thus forms a joint that allows it to adjust itself to any trifling irregularities of the surface over which it is traversed, and the rubbers

FIG. 201.



admit of being readily removed when the plates of glass have to be exchanged. The pressure is given separately upon every rubber by two lead weights each of about 15 lbs. fixed one on either side of the upright bar.

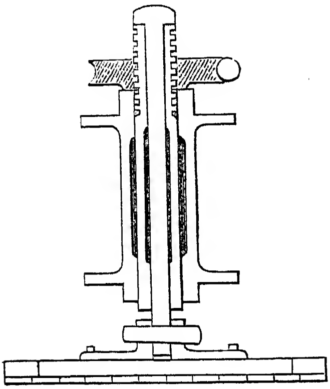
The powder generally employed for polishing plate glass by machinery is the Venetian pink of the colour-man, a cheap abrasive which contains only a small proportion of the oxide of iron mixed with earthy matter that renders the powder less active, and allows of the free use of water which serves to reduce the friction and prevent the glass becoming heated by the action of the rubbers. Tripoli, crocus, or putty powder used with water, are too active to produce a high polish on

glass with the aid of machinery, and therefore they are generally employed dry for the last finish of glass polished by hand. But the great amount of rubbing surface and the velocity and power employed for polishing plate glass by machinery, renders the use of dry powders inadmissible, as the surface would be torn by the friction and the heat evolved would be liable to break the glass.

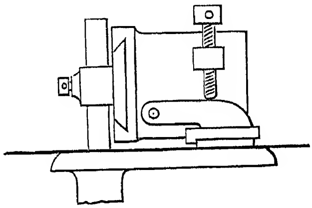
The Disc or circular grinding machines for plate glass have a large cast iron circular table from 18 to 22 feet in diameter, very true and flat on its upper surface, and similar in section to that of fig. 185, which revolves a little above the floor on the end of a vertical spindle driven by gearing below. The pieces of glass are cemented down to entirely cover the surface of this table, several of different sizes placed edge to edge and all level, the corners of some being permitted to overhang the edge to the extent of some few inches. A bridge in the form of an iron girder fixed on uprights at either end, stretches across the revolving table and carries the fixed vertical shaft or pivot for the runner at the center of its length; and it travels by wheels on the spreading feet of its uprights on rails fixed on the floor, so that it may be traversed to place the axis of the runner at any diametrical position from over the axis to the circumference of the revolving table. The runner is a flat oblong wood framing, about three-fourths of the diameter of the table in length and its width about half its length, with a socket at the center to receive the rounded end or pivot of the vertical shaft in the bridge. The true under surface of the runner is made of thick pieces of wood attached to its frame and placed edge to edge, the joints running in the direction of its length; this is sometimes covered with one or two pieces of the glass as previously described, to be themselves ground flat at the same time as the glass on the revolving table on which they rest and operate; more generally the glass is replaced and the grinding performed by thick flat cast iron bars of the length of the runner, placed between the pieces of wood and projecting from its under surface all at one level. The runner rotates upon its center from its contact with the surface of the revolving table beneath, but the axis of the one is never used over that of the other, and the distance between the two is increased and varied from time to time to equalize

the action over the entire surface of the glass plates on the table. The centers are most approached during the grinding which is commenced with a distance of nine or twelve inches between them, and, as before, is performed with two sizes of sand and one or two of emery used in succession, the runner removed and all washed thoroughly clean between every change in the grinding powders; after which the glass is smoothed in the same machine with finer powders, with the bridge moved to place the axes at about twice their previous distances.

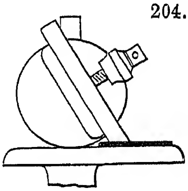
FIGS. 202.



203.



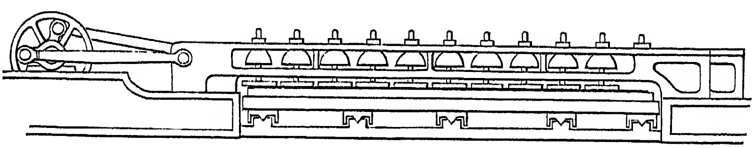
204.



The plan, fig. 201, shows one of these machines which presents some difference in details patented by Mr. B. J. Brearley, of the Union Plate Glass Works, St. Helens, 1889. The glass to be ground is cemented on supplementary rectangular platforms which are laid down on the revolving circular table and secured by clamping screws. The grinding and smoothing being completed on the one face of the glass, the platform is transferred to the table of the polishing machine and the same face is polished; after this the glass is detached, turned over and re-cemented to the transferable platform and the second face is ground and polished in like manner; the squared pieces of glass can be more conveniently arranged on the rectangular platforms than on the circular table, and half the time previously occupied in removing and refixing the glass with the attendant risk of fractures is also avoided. The runner has rounded in place of rectangular ends and is fixed to

instead of being detached from the vertical shaft or pivot, otherwise it is constructed of wood with iron grinding bars as already described. The socket on the center of the runner frame is keyed to the vertical shaft, which latter rotates with the runner and turns freely in a sleeve, fig. 202, formed of two cylinders one within the other. Neither of these cylinders rotates; the inner is cut with an external screw thread at its upper end upon which there is a worm wheel with corresponding screwed aperture, which rests and is held down on the top of the outer cylinder, fig. 201, which is itself bolted down on the surface of the bridge. The worm wheel when turned by its tangent screw on the end of a long rod, which extends to a

Fig. 205.



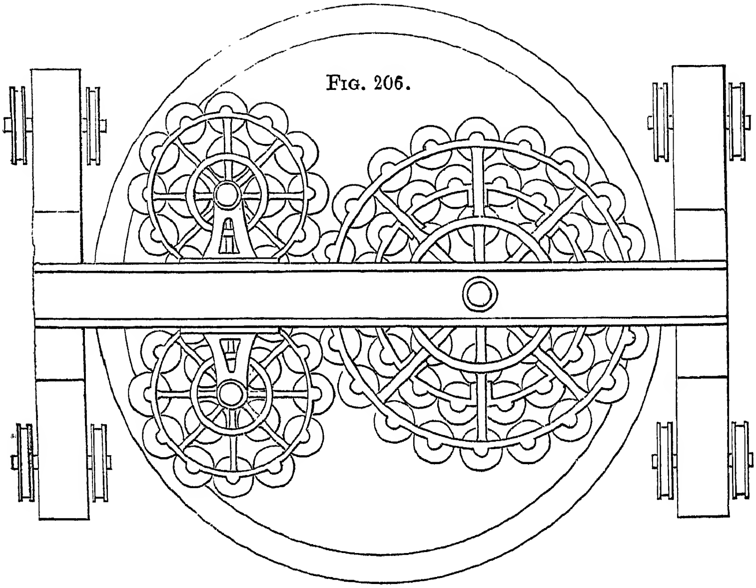
winch handle at one end of the bridge, raises the inner cylinder and with it the shaft and runner to regulate the pressure of the latter upon the glass, without the use of weights; and with the screw disengaged, the shaft and runner is lifted by a winch and chain during the removals of the transferable platforms.

The polishing machine to which the glass and supplementary platform are transferred, fig. 205, has a slowly reciprocating rectangular table which travels on rails at right angles to the traverse of the rubbers above. The latter are circular felt covered plates about 12 inches diameter, which are mounted in sets of ten or twelve pairs, by their cylindrical spindles in plain holes, in crosspieces on the upper and lower flanges and on either sides of four long iron girders; the spindle of every rubber carries a lead weight, and the spindles may also be raised and fixed while cementing the glass, or exchanging the platform on the table beneath them. The ends of the girders travel upon parallel guides, reciprocated by four cranks which stand alternately at right angles to one another so that the lines of rubbers travel simultaneously and in opposite directions.

The machines which complete the three operations of grind-

ing smoothing and polishing without the removal of the glass from the revolving table, are of the same general construction and are provided with a bridge and an iron ribbed runner for the grinding and smoothing, as already described; on the completion of the smoothing this bridge is rolled away and after the glass, table and all other parts of the machine have been scrupulously cleansed of every vestige of the emery last used, the polishing appliance is placed in position.

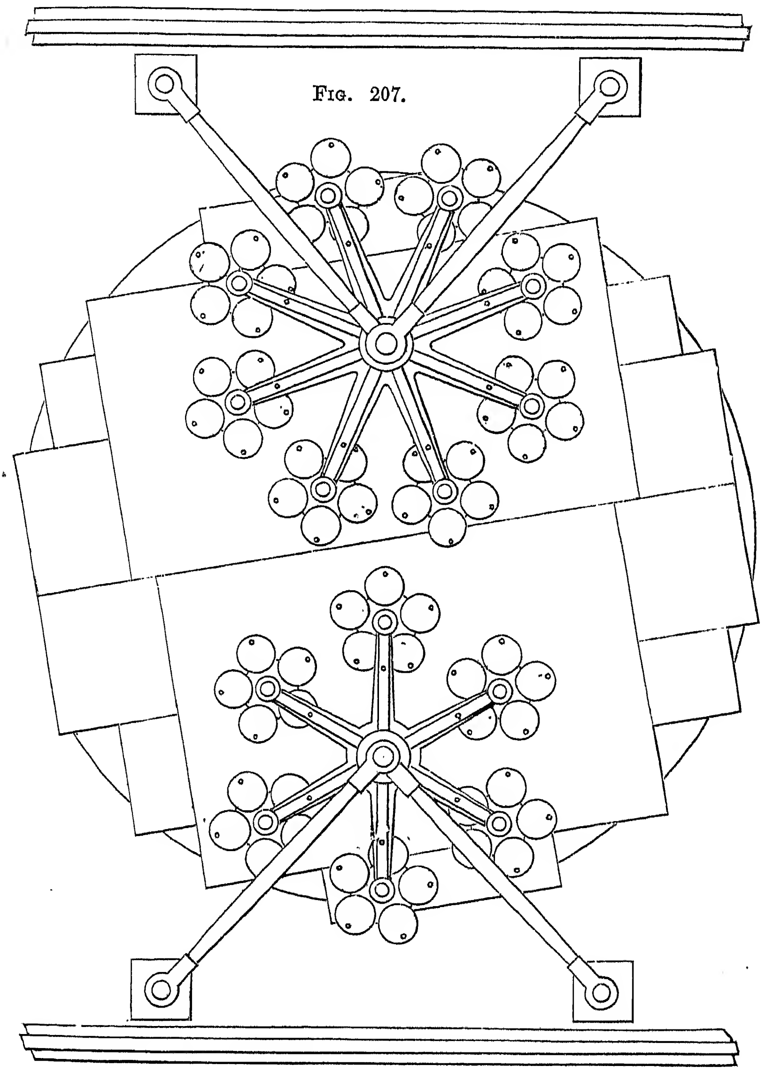
Fig. 206.



The apparatus, fig. 206, patented by M. Chas. Delrue, 1890, and used in Belgium upon machines with revolving tables 20 feet diameter, is mounted upon a second bridge similar to that of the runner, which travels upon the same rails. The polishing bridge carries the vertical axles of one large and two smaller cast iron wheels, around the felloes and upon the spokes of which the spindles of from 60 to 70 circular felt covered disc rubbers of about 14 inches diameter are arranged concentrically. The three wheels and the spindles of the rubbers are all free to revolve, so that the rubbers rotate from their contact with the revolving table and at the same time cause the rotation of the wheels which carry them, and thus impartially distribute the polishing action over the whole

surface of the glass. Forked levers jointed to loose rings held between collars on the upper ends of the polishing wheel shafts, their fulcrums mounted on the bridge, with their longe

FIG. 207.



ends actuated by vertical screws upon its end supports, are employed to press the rubbers down on the glass on the revolving table during the polishing.

The apparatus, fig. 207, patented by Messrs. Smith &

Binney, 1891, and used at the London and Manchester Plate Glass Company's Works, St. Helens, upon a machine with a 21 feet revolving table, is suspended above the latter from the roof of the workshop and lowered on to the glass after that has been ground, smoothed and cleansed and the grinding bridge rolled away. It consists of two "spider" or star shaped castings which rotate on short vertical shafts or axles and carry the rubbers at the ends of their arms, each of which rubbers is formed of five circular discs connected together in one group in the solid, and the projecting under surface of each disc is covered with felt as usual. The pivots upon which the rubbers turn have a vertical play of about half an inch in the bushed holes in the ends of the arms, and the spoked frames which carry them are also free to move vertically upon the short axle shafts upon which they revolve, so that as the spiders and cinquefoil rubbers individually rotate from their contact with the revolving table below, the rubbers are able to yield to any small inequalities in the surface of the glass fixed upon it. The upper ends of the two axle shafts terminate in rings for the chains of the hydraulic apparatus used to hoist or lower the polishers, and the pivots are screwed and provided with nuts and collars above the arms to lift the rubbers with the spider.

The polishers when resting on the glass are retained in position each by two tie rods, which have the plain holes in their one ends, one above the other, on the vertical central shafts, and the similar holes in the other extremities of the rods dropped upon corresponding round pins on the tops of pedestals fixed to the floor on either side of the revolving table close to the rails for the bridge. The arms of each pair of tie rods stand at right angles to anchor the polishers, fig. 207, but when the latter are raised, the rods on each are placed in a line to balance one another that the polisher may not cant but lift directly from the glass. Every leaf in each of the cinquefoil rubbers is also partially pierced with a hole and there is a corresponding hole in each arm of the spider, and should the felt on any one of the discs become torn during the polishing, a pin is dropped through the arm into such disc to temporarily arrest the rotation of the group of which it forms a part, and to retain the damaged rubber towards the center of the spider

to prevent the torn edges of its felt from catching against the corners of the glass which overhang the margin of the revolving table. Lifting the polishers well above the machine during the grinding and smoothing effectually prevents their accidentally acquiring any stray grains of the coarser powders then used, a contamination it is most difficult to entirely avoid in most of the machines used for both grinding and polishing. Plate glass of all dimensions is ground, smoothed and polished on the above mentioned 21 foot diameter disc machine, up to the largest it will carry, which pieces measure about 15 feet long by 11 feet 6 inches wide.

Old plate glass, that has become scratched, is sometimes repolished; when the plates are large and sufficiently numerous they are repolished by machinery, just the same as new glass, but more generally old plates are repolished by hand, as the process can be then restricted principally to the scratched portions of the surface. The polishing is commenced with tripoli on cloth rubbers of the usual form, and finished with putty powder or crocus. The pressure is generally given as in hand calendering, by attaching the rubber to the lower end of an upright pole suspended from a long horizontal spring fixed overhead, like that of a pole lathe. The elasticity of the spring allows the weight of the pole and rubber to supply the pressure and the workman has only to push the rubber backwards and forwards, but the process is both laborious and tedious with large plates and from the irregular action of the hand the surfaces of glass thus repolished present a wavy appearance much inferior to their original condition.

Sheet or flattened glass is manufactured by blowing the glass first into the form of a spherical bulb, which is afterwards elongated by alternate heating, blowing and swinging, into a cylinder about 3 feet long and 8 inches diameter, with rounded ends, which, as the last process of blowing are opened out, and the ends cut off smooth with a diamond traversed in an upright frame around the cylinder, and the latter is then cut through on the one side longitudinally with a diamond inserted near the extremity of a light rod and drawn through the inside of the cylinder under the guidance of a straight

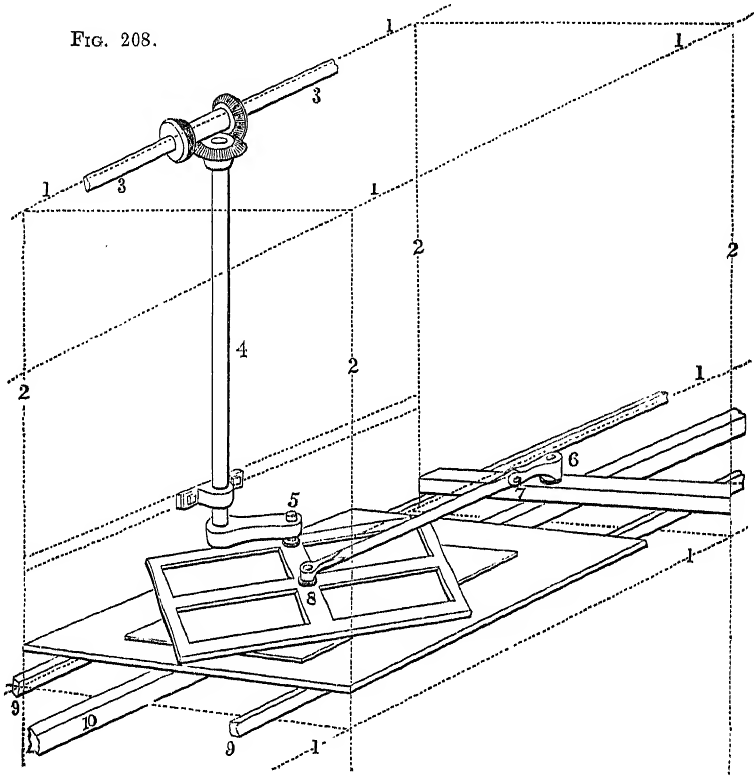
edge. The cylinder is then placed with the cut upwards in a reverberatory furnace and the heat causes it to gradually open as a sheet, which is gently flattened down on the bed of the furnace with tools like blunt garden rakes made of iron or wood. To improve the flatness several sheets are afterwards laid upon each other in a second reverberatory furnace with a level bed, the heat of the furnace and the weight of the superincumbent mass cause the lower sheets of glass to become sufficiently flat for ordinary use, notwithstanding that there are many little irregularities in their surfaces arising from the imperfect action of the flattening process. For the best purposes these irregularities are removed by grinding and polishing, and a brief notice of the method pursued in an extensive manufactory is subjoined.

The grinding room contains about 140 grinding machines, arranged in double rows of 10 each, and the annexed diagram fig. 208, may be considered to represent roughly the moving parts of every machine, the framing being represented by the dotted lines.

The framework consists of continuous beams 1, 1, united by vertical posts 2, 2, bounding every machine, the whole firmly united. Above the framing extends an axis 3, 3, carrying for every machine one pair of bevel wheels which turn the upright shaft 4, and its crank 5, to the right or left at pleasure. The pin of the crank 5, communicates a circular motion to that point of a moving table or runner to which it is attached, while the fixed radius bar 6, 7, 8 restrains the center of the table to describe an arc about the point 6, the two motions conjointly bring all parts of the running surface successively in opposition to nearly every part of the lower bed, which latter lies on railway bars 9, 9, and is very slowly reciprocated to and fro by the bar 10, which runs through the building and is traversed about two feet by a crank, that is made slowly to revolve by a worm wheel and tangent screw, one screw serving for two cranks united to two lines of the machines. The whole arrangement is most massive and imposing. The circle described by the crank 5, is about two-thirds of the length of the runner, the under face of which is covered with slate upon which the glass is cemented, another sheet of glass is cemented upon the lower table, and the runner is loaded

with 4 or 8 weights placed in the respective panels of its frame. When from swinging the runner about by hand, it is judged that one of the corners bears too hard, the weights are removed from this corner. Coarse emery and water are used

FIG. 208.

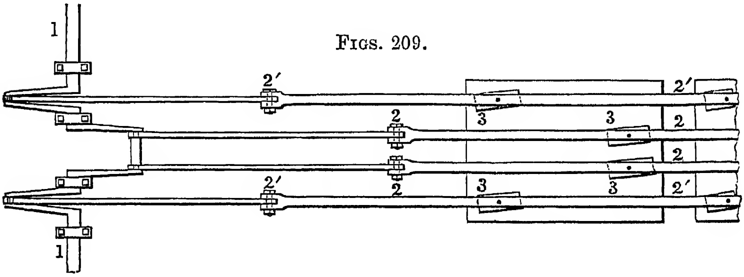


for the grinding, and when the machines are used with finer emeries for smoothing, the whole apparatus is carefully washed, for the convenience of which there are numerous racks and tanks between the rows of machines. In some manufactories the plates of glass are smoothed by rubbing them one upon the other by hand.

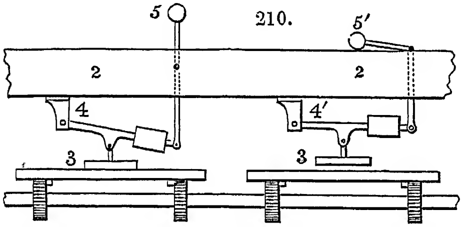
After the sheet glass has been ground flat and smoothed, it is polished in another room by the machinery indicated in figs. 209 to 211. 1, 1, is a long main shaft extending throughout the length of the building, and having for every row of the machines one double and two single cranks, which move the

two long central beams, 2, 2, to the right, and the two exterior beams, 2′, 2′, to the left at the same instant, by the intervention of connecting rods, as usual. The travelling beams or rods carry rubbers, 3, 3, 3, 3, about 12 by 5 inches on the

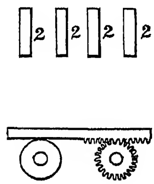
Figs. 209.



210.



211.

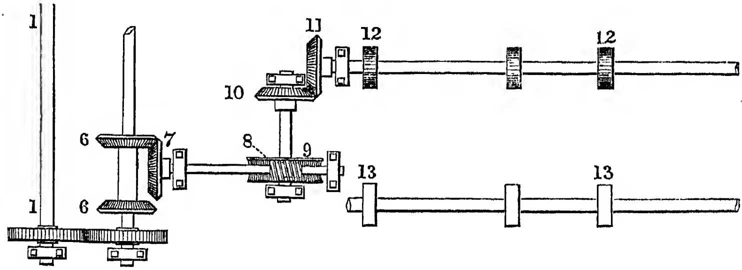


face, and covered with leather; they are suspended by a joint to the loaded levers, 4, 4′, fig. 210, which press them on the glass. To raise them up and retain them, the piece 5 is laid down in the position 5′, which holds up the lever as at 4′, as the joint which unites 4 and 5 is situated in the mortise through the long travelling beam 2, at the part represented by the dot in the figure to the left; so that when the rubber is at work the weight 5 cannot be misplaced, and when 5 is laid down as at 5′, no shaking will allow the rubber to descend accidentally. The rubbers all assume an inclined position, from the several tables carrying the glass having a very slow transverse motion, simultaneously throughout the entire line of machines, which is effected somewhat after the manner of the annexed figure, 212.

The main shaft 1, 1, communicates with a pair of sliding bevel wheels 6, 6; these through 7 move the tangent screw 8, and thence the worm wheel 9, which latter, by the pair of bevel wheels 10, 11, moves the long shaft carrying the line of pinions 12, 12, one or two of which are under every table, and

traverse the same by aid of plain rollers, 13, 13. A tumbling bob is affixed to the table nearest the cranks and gear, by which the position of the pair of bevels 6, 6, are shifted to

FIG. 212.



make the tables traverse first in the one and then in the opposite direction.

The polishing machines make about 50 or 60 strokes in the minute, and the grinding machines about 20 to 30 strokes in the minute, and every machine is so arranged as to admit of being readily detached from the others without impeding the movement of the main driving parts.

SECT. II.—GRINDING AND POLISHING OPTICAL PLANE SURFACES IN GLASS AND SPECULUM METAL.

It has been explained in the second volume, that the production of accurate plane surfaces by grinding is a process of great uncertainty, and that those of metal required in mechanical construction, are more easily and correctly produced by the methods of filing and scraping, described at pages 876, 878; but these methods are inapplicable to substances such as glass or speculum metal that do not admit of the application of cutting tools, and consequently when these hard materials have to be wrought into plane surfaces, it is essential to produce the necessary degree of accuracy by grinding alone. The grinding tool employed for the purpose is generally a flat surface of brass, supplied with abrasive powder moistened with water or oil. The surface is in most cases larger than the object to be ground, which is rubbed by hand upon the grinding tool with straight, circular, or elliptical

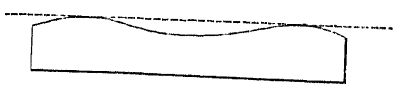
strokes, applied in all directions; but these grinding tools, although they may be originally produced by the method of scraping, soon lose the required accuracy, and from the particles of the polishing powder becoming embedded in the surfaces, their restoration by the method of scraping is impracticable.

The plane surfaces of the grinding tools themselves, have therefore to be produced as nearly accurate as possible by grinding, and the method explained on page 871 is pursued with all possible care. Three surfaces, generally of brass, are operated upon at the same time, and serve for mutual correction by being rubbed one upon the other, in the succession explained at pages 877 and 878, with reference to testing the condition of planometers produced by scraping.

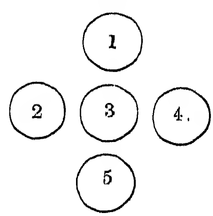
The two surfaces found to have the same error are rubbed together, first with large circular strokes, in order that the operator may feel at what parts of their surfaces they bear the hardest, or appear to hang together; these parts are then placed in contact and rubbed with short strokes, either straight or circular, applied longitudinally or transversely, according as they may feel to offer the greater resistance to the one or other motion, the surfaces being rubbed together in the direction, and just for the distance, that they appear to move stiffly upon each other. Great care is required to avoid the introduction of new errors, exactly as in scraping planometers, and the surfaces must be frequently wiped clean and tried upon each other, first to feel that they bear uniformly when tried at the four diagonals, and when these larger errors are removed, the surfaces are rubbed together with short strokes, in order that they may mutually brighten the highest points of their respective surfaces. The grinding is continued under these tests until all three surfaces feel to slide smoothly and equably over each other in all directions, the final test being that when the whole of the grinding powder is removed, and they are rubbed upon one another, the surfaces should be *uniformly* covered with small bright spots close together, so as to give the surfaces a finely mottled or bronzed appearance. The degree of accuracy required to present this uniformly brightened surface, is however exceedingly difficult to attain by the process of grinding.

In the case of plane surfaces in glass required for optical purposes, as in the parallel discs employed in sextants, great accuracy is required, and in the ordinary method of grinding and polishing much difficulty is experienced from the absence of control over the distribution of the grinding powder upon the surfaces under formation. To obviate this inconvenience, the late Mr. Andrew Ross was induced to investigate the causes which led to the inaccuracy of the grinding process, and he succeeded in pointing out the principal source of error and also the method by which it may be avoided. Upon a careful examination of the process of grinding two surfaces together, whether plane or curved, Mr. Ross found that the principal errors occurred in the direction in which the two surfaces were rubbed upon each other, and that they occur from the unequal distribution of the grinding powder. In the act of traversing the object over the metal surface the grinding powder is pushed away by the advancing edge of the object, while near its center an excessive quantity of the powder is accumulated, and consequently the object is ground concave near the middle; in the return stroke it picks up, at the extreme edges, a small quantity of the new grinding powder that has not been crushed in working, and therefore acts with more energy, and rounds off the extreme edge. The combination of the two errors, makes the object that should be a plane surface, of the irregular section shown in the exaggerated diagram, fig. 213.

Figs. 213.



214.



For optical purposes the rounding off at the edges is not very important, as the difficulty may be overcome, either by grinding the glass of a larger size than is ultimately required and afterwards reducing the diameter so as to remove the rounded edges, or the edges may be covered by a ring of paste-board or metal, so as to prevent that portion from interfering

with the accuracy of the instrument. It is therefore the concavity in the middle that is the principal difficulty in optical glasses.

Mr. Ross discovered that the accumulation of the grinding powder near the middle of the glass, arose from the capillary attraction of the *moistened* powder, and, that by the employment of the grinding powder in a *dry* state the source of the most important error was removed. The grinding powder when used dry cuts less rapidly than when moistened, but from the greater exactness of the method a much smaller amount of abrasion suffices to produce the plane surface, and consequently the dry process is but little more tedious than the wet.

In grinding and polishing the parallel discs of glass for sextants and larger pieces for other purposes, the one surface is first ground flat, sometimes singly, but more generally from motives of economy five are ground at the same time. The discs are arranged in the order shown in the diagram, fig. 214. The surface of the one and fixed tool having been wiped quite clean and dry, every disc is slightly moistened by breathing upon it. Each one is then placed upon the lower tool with moderate pressure; and if they be tolerably flat, the capillary attraction will suffice for retaining them in position during the grinding. A small quantity of finely washed emery is then dusted upon every disc, the second tool is placed over the whole, and attached to a line leading to a pulley placed overhead, from which a counterpoise weight is suspended to regulate the pressure which should be only moderate. The upper tool is then rubbed with elliptical strokes continually varied in direction, and the tools are occasionally changed end for end, in order to place the surfaces in all possible relations to each other.

The surface upon which the glass discs are attached is always the lower tool, and the emery that is pushed off them falls on the lower surface, and is not picked up by the upper tool in the return stroke, which as previously mentioned, would be liable to round the extreme edges. By this arrangement it is only the tolerably uniform layer of emery that remains attached to the upper grinding tool that is employed, and the principal dependence for flatness is placed upon the

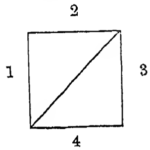
condition of this tool. Water is used with the emery by most opticians, but by Mr. Ross the emery was used dry, and, to examine the progress of the work, the upper tool is removed and the grinding powder blown away with a pair of bellows, as wiping with a cloth would leave particles of the powder attached to the face of the glass. When the discs have been ground flat over their whole surfaces on one side, they are removed from the lower tool, which is thoroughly cleaned; they are then arranged as before, with their second faces upwards, and ground flat. But it will now happen that the two sides, although they may be plane surfaces, are not parallel with each other, and therefore the positions of the discs upon the lower tool are interchanged, 1 being placed in the position of 5, and 2 in that of 4, and the central one is twisted round in the opposite direction. The whole are then ground in the same manner as before, until flat in their second positions, when they are again interchanged; and the process is repeated until both sides of the discs are made quite parallel with each other, and they collectively present a level surface in whatever order they may be arranged upon the lower tool. The discs are lastly polished either with oxide of iron, or putty powder.

In the machines used for the foregoing purposes the pieces of glass are placed on the true flat surface of the lower tool, sprinkled with the grinding or polishing powders, and the upper tool is rubbed upon them set in motion by an eccentric, the same routine being followed as to changing their sides and positions. Planes in glass are also sometimes prepared by grinding on the surface of a revolving lap, but owing to the expansion of the glass from the heat evolved the process does not yield a true plane,—which in optics it should be remembered requires considerably greater accuracy than the metal planes which suffice for the purposes of the engineer,—hence the work has to be corrected and completed on the fixed flat grinder.

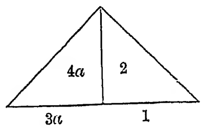
The production of the planes of optical prisms, a more tedious and difficult operation, is conducted sometimes on revolving laps, but preferably and more accurately upon the fixed tool; the system followed is the same upon either. The prisms generally are quite small, measuring from about

¼ inch to about 1 inch square upon their right-angled faces; the truth of the angle of 90° at which these meet is important, but that of 45° at which the hypotenuse or third side meets them is essential, and the planes of the three faces must be parallel as well as true individually.

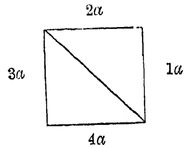
FIGS. 215.



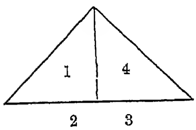
216.



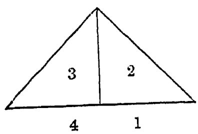
217.



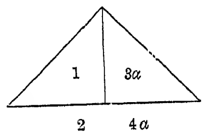
218.



219.



220.



Several pieces of glass are first ground to true cubes, of which the four parallel planes are numbered 1, 2, 3, 4, as seen from one end of the cube in the diagram fig. 215, and 1*a* 2*a* 3*a* 4*a*, as viewed from the other, fig. 217; and these cubes are then slit across from corner to corner with the thin iron slicer used by the lapidary charged with diamond powder and lubricated with oil or paraffine. The right-angled faces 1 and 4 of any pair of the resulting triangular pieces are then cemented together, and the base formed by their neighbours 2 and 3 fig. 218 are ground as one plane; detached and recemented by the sides 3, 2, just ground, the faces 4, 1 are ground and corrected together in like manner, after this one piece is turned end for end and the same practice pursued to grind faces 2 and 4*a* and 3*a* and 1, as single planes; when all have been so treated, the halves of different cubes are cemented to those of others and the grinding continued until by continual changes the right-angled sides are corrected true and parallel, the grinding being effected by the use of gradually finer emery and water. The hypotenuse sides are next ground under careful measurement as to the angle produced and, according to individual practice, either with the two pieces still cemented together or every prism separately. The same routine is then followed for the polishing with putty powder, by which process

the planes are completed to final truth, their correction being made under the guidance of constant optical testing. In France sand and water are employed for grinding and rouge for the polishing; for the latter the polisher is covered with a tough kind of blotting paper and the powder is used dry.

The cemented prisms are held in the fingers or, when numerous, several such pairs are ground at one time in a *block*, a metal ring, fig. 223, sufficiently large to hold from 4 to 6 pairs and rather deeper than the height of the prisms. To prepare the block the ring is placed on three lifting pieces so as to stand a little above a true surface, the cemented pieces of glass are then arranged on the latter equidistantly within the ring and not touching one another and the ring is filled with liquid plaster of Paris or Parian cement to secure them, when this has set the whole are ground or polished together, with the ring as a handle; the plaster is broken out and the block re-made with every change in the faces ground or polished.

Prisms have been cut from time to time in the precious stones, usually for the study of the refractive properties of these bodies, and the following brief reference to the productions of an eminent optician are of great interest. Mr. Adam Hilger, of London, has several times cut them in the diamond, sapphire, tourmaline and other stones, among them being a collection made for M. Tournow, a Russian savant, the most remarkable in which was a 60° prism measuring a little more than 1⅛ inch high on one right-angled face by ⅝ of an inch square on the other or base, the largest dimensions that could be worked from a large diamond of great value, of good colour and without flaw. The grinding of the prism to shape and truth was effected with comparative ease upon the surface of a horizontal iron mill or lap fed with diamond powder and oil, which was mounted as in fig. 52, and like that was driven by a foot treadle, this slow speed compared with that usually employed in diamond cutting being purposely adopted to avoid heating the diamond, and any distortion in the truth of the planes in the prism that might arise therefrom. After its approximate reduction, the further grinding was conducted with the diamond mounted in the center of a small block,

fig. 223, with four bearing pieces of diamonds, equal in hardness but otherwise of inferior quality to the central diamond, placed at a little distance from and equidistantly around it, the whole secured in the ring with Parian cement; the diamond and the bearing pieces, therefore, represented one large plane of which the latter were in the margins, in which position they guaranteed the truth of the face ground on the diamond in the center of such plane, by taking to themselves the slight rounding off which always occurs upon the extreme margins of surfaces ground on revolving laps, and it is for the same reason among others that the frequent interchange of positions of the prisms is made in grinding optical glass prisms.

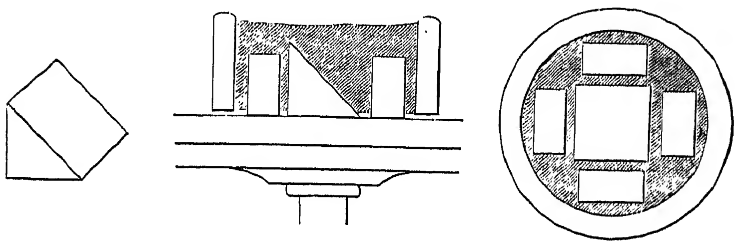
The subsequent corrections to absolute truth in the polishing, first conducted in the same manner on the iron lap with finer diamond powder, presented unexpected difficulties, as notwithstanding the utmost care the process was found to leave the otherwise true and polished faces full of microscopic striæ.

After numerous experiments with different laps and powders Mr. Hilger was led to the apparent paradox of polishing the hardest with the softest materials. The diamond prism already corrected to truth was finally polished, held in the fingers on a revolving pitch polisher made of the constituents ordinarily employed and mentioned later, but to which a large proportion of wax was added to render them still softer, and this polisher driven by the foot as before, was fed with finely sifted wheat flour only. This remarkable instance of abrasion was entirely successful but very slow, the polishing of the diamond occupied three weeks of continuous working days, whilst the grinding it to shape took not much more than as many days. Mr. Hilger informs the writer that, on looking through the prism, the beam of light instead of being perfectly clear as in glass, appeared completely filled with minute brilliant scintillations. This was probably due to the structure of the diamond itself, its form being nearly always an irregular octohedron, and its crystallization parallel stratifications or layers from a nucleus to all its external planes, its lines of cleavage; hence the infinite layers and the angles of their meetings throughout the substance of the stone, stood at an endless variety of angles to the planes of the prism to which

the diamond had been cut, and thus produced this beautiful effect.

The right-angled faces of optical prisms rarely exceed about one inch square, but some measuring 6 inches were successfully completed, separately, by Lord Blythswood at his laboratory at Blythswood, Renfrew, as follows. The piece was cut from a block of glass and ground to shape and approximate truth by hand, after which, stood on one right-angled face upon a true surface plate, it was mounted centrally in a deep metal

Figs. 221. 222. 223.



ring with four pieces of glass of the same quality and about 3 inches wide, equidistantly around it, and the ring was filled with plaster of Paris. The first plane when ground accurately flat was very carefully adjusted vertically within the ring, the bearing pieces and the plaster were put in as before and the second face ground, after which the third was completed in like manner. The errors pointed out by the optical tests were gradually corrected by many repetitions of the smooth grinding and the polishing, each conducted with the prism remounted in the ring. Notwithstanding the most practised manipulation in the readjustments of the prism throughout all these correctional operations, the diminishing errors did not disappear but they also varied in their incidence; this was eventually found to be solely due to the use of plaster of Paris, which material even when perfectly hard and set proved insufficiently dense and to yield with work of so large a size. Lord Blythswood substituted Parian cement, used then for the first time for this purpose, which at once overcame all difficulty, and held by this material, which at every readjustment was allowed 48 hours to set before the polishing was recommenced, the 6 inch prisms were completed to a very high degree of accuracy.

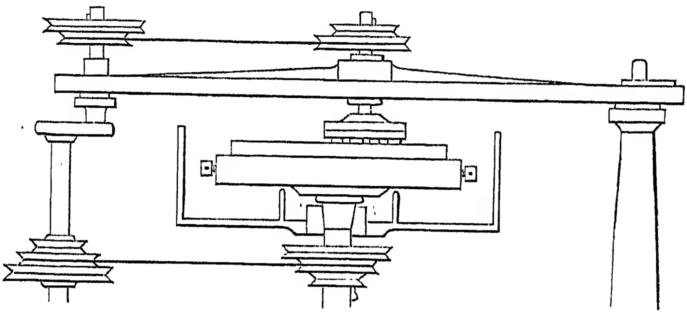
Plane mirrors made of speculum metal employed in reflecting telescopes, are ground to a plane surface upon flat grinding tools prepared as lately described. The grinding tool is much larger than the specula to be ground, and is supplied with a small quantity of fine washed emery, and the specula are rubbed singly upon the tool, with the fingers like a muller, until they are ground perfectly flat. The principal difficulty is, however, experienced in producing the high polish required in reflecting surfaces without impairing the accuracy of the plane surface obtained in grinding. The polisher is generally of cast iron, grooved over its entire surface so as to divide it into squares, and covered with pitch, or a resinous cement, exactly in the same manner as in the polishers used for concave specula, the methods of working which will be briefly described in the chapter on spherical superficies. Great importance is attached to the sizes of the polishers relatively to those of the specula, as if the polishers are made too large, the edges of the specula will be rounded off, or made convex; and if the polishers are made too small, the specula will be wrought concave.

Small plane specula are usually polished several at the same time. They are arranged close together to make up a circle, and with their faces quite level. The polisher is also circular; and Mr. Ross considered that the specula are most accurately polished when the diameter of the polisher is about one-thirtieth greater than that of the circle of specula.

Elliptical specula, measuring above 3 inches by 2, are commonly polished singly, and with most success with a round polisher of the same size as the lesser diameter of the oval. The late Earl of Rosse found that he was enabled to polish specula of this size very perfectly with a polisher of three inches diameter applied in his machine for grinding and polishing concave specula briefly described in Chapter VIII. On this subject the Earl of Rosse has said: "When the metal is polished, it is tested in the usual way by viewing an object alternately by direct and reflected vision, with a very good thirty inch achromatic, the aperture of which has been previously contracted to an inch and three quarters. If the metal is concave, it is worked with shorter strokes for about half an hour, and then tried; it will be found to have become

less concave, possibly convex; in the latter case it is to be worked with longer strokes; thus, with the utmost facility, a metal can be worked alternately concave and convex; and, with a little practice, the limit between the two can be hit with such exactness, that, even with the severe test of a thirty inch achromatic, no deviation from the plane can be perceived, and the loss of light will be the only evidence that the rays have suffered reflexion before their incidence on the object glass."

Fig. 224.



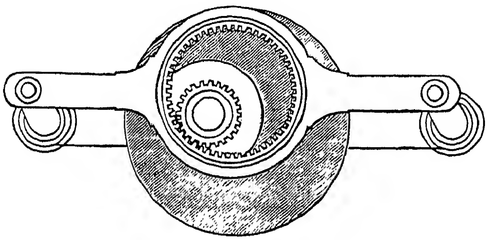
The apparatus contrived and used by Lord Blythswood for grinding and polishing small plane specula, indicated by the diagrams figs. 224—226, consists, for the grinding, of a flat circular gritstone about two feet diameter fig. 224, which is held by binding screws around its edge within the rim of a surface chuck that revolves on the top of a vertical spindle. The chuck is surrounded by a metal casing to catch the sand and water, which casing has a second vertical ring within it, rising nearly into contact with the under side of the chuck, that is loosely filled with cotton wool to prevent the grit finding its way to the collar of the spindle; the used sand and water flows away through a pipe to a receptacle below, from whence it is raised by a small turbine and redeposited through a pipe on the surface of the stone.

A mahogany bar about five feet long stands horizontally above and diametrically across the stone, supported and sliding at one end by a gun-metal lined slot on an upright with a fixed steel pivot, and resting at the other by a gun-metal sleeve, turning in a bushed hole in the bar, on the vertical pivot of a crank, which latter is placed in revolution

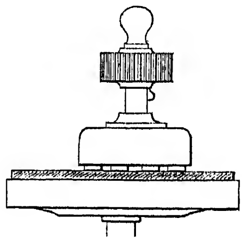
from the grinding spindle by a band and speed pulleys below. The several pieces of speculum metal are cemented, one centrally and the others equidistantly around it, on the flat under surface of a weighted circular holder, about seven inches in diameter, provided with a central spindle which passes through a bushed hole in the mahogany bar and terminates above in a pulley with speed grooves keyed upon it which, with the holder, is driven by a band from a corresponding pulley on the sleeve on the vertical pivot of the crank, the sleeve slotted and the pivot provided with a feather; the sleeve is retained in the bar by a shoulder above and a nut and washer upon it below, so that the bar and all it carries may be lifted together off the grinder to examine the progress of the work. The action of the machine causes every point upon the surface of each piece of speculum metal to travel in a quasi-epitrothoidal path, which is not an exact circle of loops fig. 269 as performed in M. Lascelles' machine, but a continuous circuit more or less oviform, round on the one side and slightly compressed or pointed towards the other. The grinding stone used for roughing down the pieces of speculum flat is exchanged for a similar grinder of solid water of ayr stone, which smooths and leaves them with a dull grey polish. This stone is used with water and the former with finely sifted sand and water, but both soon become smoothed and lose their cut by the rubbing of the hard speculum metal and require their surfaces and cutting qualities renewed from time to time by turning, effected *in situ* by a carbonate diamond tool traversed across them mounted in a screw slide above with the mahogany bar removed.

The polishing is carried out in a separate machine shown by the plan diagram fig. 225, which has a flat circular pitch polisher of the construction shown by figs. 266-267, slowly revolving on the top of a vertical mandrel. A metal ring of about 12 inches internal diameter cut with fine teeth as an internal spur wheel and provided with two diametrical arms about 12 inches long, is mounted parallel with and rests above the polisher by plain bushed holes at the ends of its arms on the pivots of two equal cranks by which it is swung round in a circle; the vertical shafts of the cranks have equal speed pulleys connected by a band and one of these shafts is driven

at a slow speed. The pieces of speculum are cemented to the under surface of a heavy circular disc of rather less diameter than the aperture of the ring, and this holder, shown detached fig. 226, has a fixed central post surmounted by a deep spur wheel about six inches diameter keyed thereon. The centri-



FIGS. 225.



226.

fugal action of the pitch polisher and the swinging circular movement of the ring cause the holder to travel away from the axis of the polisher and its spur wheel to engage in the internal teeth of the ring, by which the holder is forced to continually rotate upon its own axis and at the same time to be continuously carried round and round within the circle of the ring; and the result of this very neat construction is that every point on the surface of each specula travels in the exact path shown by fig. 269. The work-holder being of smaller diameter than the aperture of the toothed ring, it may be always lifted out to examine the progress of the polishing.

CHAPTER VII.

THE PRODUCTION OF CYLINDRICAL AND CONICAL SURFACES BY ABRASION.

SECT. I.—GRINDING EXTERNAL CYLINDERS IN METAL.

Cylindrical works in metal of small diameter and considerable length, such as slender rods, are difficult to turn of strictly uniform diameter because, from their weakness, they are liable to spring away from the turning tool. This liability is, to a considerable extent, counteracted by the application of supports called back stays or sliding guides, which are adverted to in the succeeding volume; but, nevertheless, after slender rods have been turned as nearly uniform in diameter as possible they still retain numerous irregularities, which, although not observable to the eye, may be readily detected by passing the rod between the fingers. Shorter or thicker cylindrical rods that are too rigid to spring from the tool, are nevertheless liable to slight irregularities arising from imperfections in the slides of the lathe in which they are turned, hard and soft places in the metal, and also from the wear of the tool, which, although small, is quite appreciable in works of moderate length. These circumstances combined, render the attainment of a perfectly cylindrical rod by turning a matter of considerable practical difficulty; and consequently, it is usual after the work has been turned as true as possible, to reduce the minute errors by grinding, which, at the same time serves to give the work a more highly finished appearance. The above classes of work which only require a moderate degree of accuracy are usually ground between lead or tin grinders of counterpart form, supplied with emery and water, or oil, fixed in iron clamps that supply the pressure, and serve as handles for the application of the grinders.

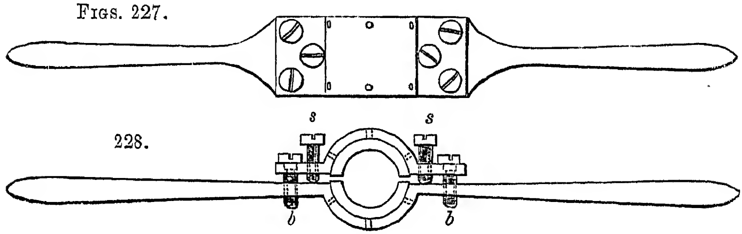
Figs. 227 and 228 represent in two views a grinding clamp suitable for cylindrical rods of medium size. The two halves

of the clamp are connected at each end by two binding screws, *b*, and the clamps are curved in the middle, so that when they are separated about one-quarter of an inch by the set screws, *s*, they may present in the center a cylindrical aperture about one inch larger in diameter than the cylinder to be ground.

For casting the lead grinders within the iron clamps, the set screws are withdrawn and the binding screws slackened

Figs. 227.

228.



so as to leave an opening of about one quarter of an inch between the flat faces of the clamps, which are then placed edgeways upon a flat block, and a short cylinder or core of the same diameter as the cylinder to be ground is placed in the center of the circular aperture; two parallel slips of wood or iron sufficiently wide to be grasped between the flat faces of the clamps, are then placed in contact with the sides of the core, so as to divide the opening into two parts, and are firmly pinched by the binding screws. Melted lead is now poured in to fill up the cavities, and form two grinders, each a little less than the semicircle, the cylindrical faces of which are counterparts of the metal core. The inside surfaces of the clamps are left rather rough, in order that they may the better hold the lead; and, with the same view, a few radial holes are sometimes drilled in the clamps, or otherwise the edges of the opening are chamfered off, in order that the lead may be cast with a projection on each side to prevent the grinders from shifting endways. To keep the core in the center of the clamp while the lead is being poured, a hole is sometimes bored in the block upon which the clamps are laid. At other times the grinders are cast at once upon the rod to be ground; in this case the rod is fixed vertically in a vice, and a hole is bored through a piece of wood, which is slipped on the rod, and luted with clay to make a close joint.

In grinding a long cylindrical rod, the work is mounted in the lathe and the grinder is fitted upon it by first closing the clamps with the binding screws *b*, the set screws *s* are then advanced to partially sustain the pressure of the binding screws, and to separate the clamps just sufficiently to allow the rod to revolve within the grinder, with as much friction as can be conveniently overcome by the hands applied to the extremities of the handles. The lathe is then put in rotation, and the grinder is traversed backwards and forwards throughout the length of the rod, with a twisting action somewhat as in boring a hole with an auger. If the grinder were slowly traversed straight along the rod the latter would not be so uniformly ground, and when finished it would be marked with rings partly owing to the emery not being equally distributed over the surface of the work. The grinder is first applied to those parts of the rod which present the greatest amount of friction, and when the resistance becomes lessened at these most prominent parts of its length, the grinding clamps are closed upon the rod by withdrawing the set screws and tightening the binding screws. The clamps thus admit of being gradually adjusted, so as to serve almost as a gage for the parallelism of the rod, and successively reduce the parts of largest diameter, until the grinder slides smoothly and with uniform resistance from end to end of the cylinder.

The grinder should be as nearly as possible the counterpart of the desired cylinder, but in the course of work it becomes irregularly enlarged, while at the same time the cylinder is gradually although slightly reduced; the closing of the clamps partially compensates for the difference of diameter, but not for the irregularity of wear, and consequently two grinders are usually required for the completion of the cylinder. The principal errors are removed with the first, and when the rod has been rendered tolerably cylindrical and very nearly of the required diameter, a second grinder is cast for finishing the work.

When the rods are required to be of precise diameter, for sliding through bearings and similar purposes, they are turned slightly larger than the finished size and gradually reduced by grinding, until upon trial they are found to fit with sufficient precision within the hole in which they are intended to work.

Sometimes brass or gun-metal grinders made in halves, connected by screws and bored out to the exact diameter, are employed for the final adjustment of cylindrical works required to be of definite diameter, but the method is scarcely trustworthy, as the grinders are themselves rapidly abraded and soon become enlarged unless they are very sparingly employed.

Short cylinders are in many cases ground by hand instead of in the lathe, the work is then fixed horizontally in the vice, and the workman stands in front of the end of the cylinder, and twists the grinder about half way round backwards and forwards and at the same time traverses it to and fro lengthways on the work, varying the direction of the stroke as much as possible every time and occasionally twisting the cylinder partly round in the vice, in order to expose it more equally to the action of the grinder, which is fitted upon the cylinder and applied to reduce the high points in succession, just the same as in the lathe process. This method is less rapid than grinding in the lathe but is more under control, as the resistance offered by trifling irregularities is more easily appreciated when the work is at rest than when it is revolving, and from the constant change of the path of the grinder the cylinder is less liable to be marked with rings.

When the cylinder terminates at the one end in a collar or projection, it is rather difficult to grind the work square in the corner, partly owing to the angle of the grinder being worn away. In this case tin is generally used instead of lead for the grinder, which is also made narrow in order to allow of as much of the traversing or screwing action as possible, and to partly avoid the liability of the grinder to become more enlarged at the ends than in the middle.

Large cylindrical works, such as rollers, present too much surface friction to be ground between clamps, and for those purposes which only require moderate accuracy, the works are left sufficiently true from the lathe, and the surfaces are polished as explained for large turned works in the catalogue, MACHINERY, article 1. Works requiring a little more accuracy are sometimes smoothed with a grinder, made by casting a lump of lead upon the cylinder to embrace about one-third of its circumference, and weighing from one to two hundred

weight, with a bar of iron 3 or 4 feet long inserted in the loam mould at the time of casting, to serve as the handles. The roller is made to revolve in the lathe, and the grinder, mounted upon the roller, is traversed backwards and forwards by the handles, the weight of the grinder supplying the pressure.

Many cylindrical works, such as lathe mandrels, gages for the diameters of holes, flatting rollers for thin gold wire, and other similar objects, that are required to possess considerable accuracy and durability, are made of steel and afterwards hardened, in which latter process they are liable to become distorted, as explained in Vol. I. Chap. XII. Sect. IV. These works are usually ground before hardening, with the clamps, fig. 228, but which method is not sufficiently accurate for the final correction of the best works, as the grinders have a constant tendency to wear of an oval figure and also to become rounded in the direction of their length from the outer edges being more rapidly worn than the middle, this partly arises from the absence of a sufficient guide to ensure the grinder being traversed parallel with the axis of the cylinder, as the shortness of the grinder allows the handles of the clamp to be imperceptibly twisted from the square position, in opposite directions with every stroke. To avoid this liability as much as possible in works requiring tolerable exactness, the grinder is made as long as admissible and the handles very short, in order to reduce the leverage, the finishing clamps being sometimes no longer than is required for the binding screws, which are only tightened so far that the grinder just touches the highest points of the cylinder to allow of its being traversed with very moderate force, so that small inequalities may be detected by the sense of touch, and in this manner a sufficient approach to correctness for many works is readily attained. But although with careful management the work may be made tolerably circular in this manner, the practice is deficient of any correctional process that can be relied upon for the absolute straightness of the cylinder.

A more accurate method is to mount the cylinder in the lathe, and to apply a fixed grinder in the sliderest, exactly like a blunt turning tool. The grinder is made of lead, copper or iron, supplied with fine emery and adjusted so as just to

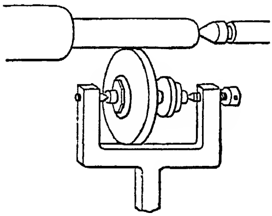
touch the highest points of the work as it revolves with moderate velocity. The grinder is traversed from end to end of the cylinder by the sliderest and, as the highest points are gradually reduced, it is set forward to remove the next series of prominences and so on. The true circular form may be at once attained by this method, and the parallelism of the cylinder will depend upon the perfection of the sliderest and the accuracy with which it is adjusted.

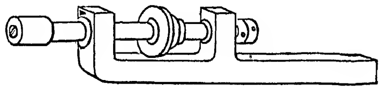
Cylindrical works in steel in which the length much exceeds the diameter, or which are pierced or of annular form, are very liable to distortion from the process of hardening. These, therefore, for accurately true form, are first prepared a trifle larger than their finished dimensions and are then reduced to their definite sizes after they have been hardened by grinding, during which process they also re-acquire their cylindrical truth. The correction it should also be said is occasionally effected by turning with a carbonate or other diamond tool, fig. 391, clamped in the sliderest, and the varieties of these tools together with some peculiarities in their manipulation and in that of the lathe in which they are employed are fully described page 347, Vol. IV., and are further discussed in a later chapter; but the correction is far more generally made by grinding, sometimes with a fixed grinder, but usually with the edge of a revolving emery wheel or metal lap.

The emery wheel used for hardened steel cylinders of moderate dimensions is of fine grain, from three to five inches in diameter and from a quarter to three quarters of an inch in thickness; it is mounted on a steel spindle with a small driving pulley, which runs between centers in the fork of a strong iron frame, fig. 229, the stem of which is clamped in the sliderest. The spindle is driven at a rapid pace by a catgut band from a drum above, some three or four times the diameter of the pulley, or from some other form of overhead motion which will allow the band to traverse the length of the work. The latter revolves at a slow rate and in the opposite direction to the grinding wheel, and very little pressure is given that the truth of the work may be gradually recovered during the reduction of the hardened cylinder to its finished diameter, both which results are more accurately attained by

many light traverses than by fewer of more vigorous action, which also avoids the risk of springing the work upon the centres by which it is supported. It is requisite that the edge of the emery wheel should be both flat and cylindrical, and it is good practice to occasionally re-instate these particulars by traversing the wheel upon another running in the lathe in the

Figs. 229. 230.





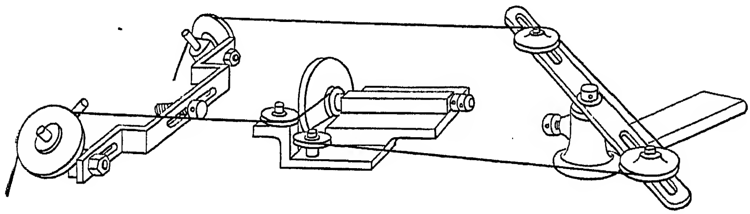
same manner as the work; the extreme corners of the periphery of the emery wheel are also removed by holding a piece of an emery wheel against them when in revolution, just sufficiently to prevent them from bearing on the cylinder. Lead and tin laps alloyed with antimony, as mentioned in the catalogue, are used in precisely the same manner and give a smoother result, especially when it is required to grind the cylinder true quite up into a corner against a shoulder in the same solid. It is also common to commence the grinding with the emery wheel and to conclude it with the lap; the metal wheels retain a better arris and are more easily repaired or shaped to any other form than cylindrical, they are charged with fine grinding or flour emery or with the finer powders for finishing, rubbed into their edges with a flint pebble and water in the manner already described.

Plug gages for measuring holes are ground to their diameters with a succession of gradually finer emery wheels, after they have been hardened, in precisely the same manner, and are finished with the finer polishing powders applied on metal laps. Their reduction to accurate diameter requires most careful watching and constant testing or callipering, but their true parallelism, as with all these cylindrical works, depends entirely upon the accuracy of the lathe and sliderest.

When the lathe is unprovided with an overhead motion, the emery wheel is driven by the apparatus fig. 231, or by some

analogous arrangement. A band from the fly-wheel of the lathe drives the mandrel and the work, and a second band from the fly-wheel is led over a pair of guide pulleys which are adjustable to fix at the required vertical inclinations, height and distances apart, upon a horizontal bar, shown to the left of the illustration, that is clamped resting on the

Fig. 231.

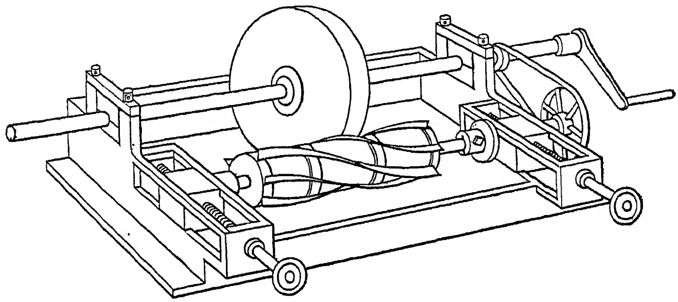


bearers against the face of the lathe-head. The emery wheel is mounted on the end of a spindle, with a small driving pulley behind it, which runs in a square stem parallel with the work; the stem is fixed to a bent plate that carries a pair of small horizontal pulleys one above and to the side of the other, and is clamped on the sliderest. The band runs around the upper horizontal pulley to that on the spindle, then back around the lower to a pair of stretching pulleys adjustable on a bar carried by the pedestal of the ordinary hand rest, which is clamped on the lathe bearers beyond the popit head, and thence over the further vertical guide pulley back to the fly-wheel. Crossing the band from the two small pulleys to that on the spindle or letting it run open drives the emery wheel in the opposite or in the same direction as the work, and the three pieces described are convenient and readily mounted upon or withdrawn from the lathe.

The ordinary gritstone is employed in a hand machine, fig. 232, for grinding the cylindrical helical edges of the spiral knives of the rollers of grass-mowing machines, patented by Mr. Gibbons, 1881. A rectangular frame in one solid with its base plate forming a tray to catch the water, has square iron blocks at each end which are advanced by screws turned by hand wheels to press the roller against the stone. A spindle passes through the right hand block and its enlarged inner

end is bored with a cylindrical hole and provided with split dies and a binding screw to grip one of the pivots of the roller knife, and its other end carries a star or peg wheel externally to the frame. The opposite block is pierced with a plain hole and receives corresponding short collars, bored to receive various sized pivots for the other end of the roller. The grindstone of about 18 inches diameter is mounted centrally upon a long round shaft, the left hand half of which is cut as

FIG. 232.



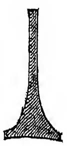
a screw of ten threads to the inch, and travels through a screwed bearing; the other and plain half of the shaft is grooved throughout its length and slides freely through its bearing and through a second pegged wheel provided with a feather, and half the diameter of that on the spindle, which turns and is held against the outer side of the bearing, beyond which the shaft terminates in a winch handle. The two wheels are connected by an endless chain with a small stretching pulley below, and the shaft turned by the winch handle slowly traverses and revolves the stone and rotates the roller, the two turning in opposite directions.

The foregoing simple machine copies a part of the practice followed in grinding the more accurate but similar cylindrical helical knives on the rollers used for shearing or cropping the nap on woollen cloths. In the machines for this latter purpose the cloth strained on rollers passes between the narrow rounded edge of a long cast-iron bar, *a*, called the *bed*, which is fixed below it, and the sharp bevilled edge of a steel plate of equal length, *b*, called the *blade*, and the helical knives on the roller, *c*, usually called the *spirals*, both of which are adjust-

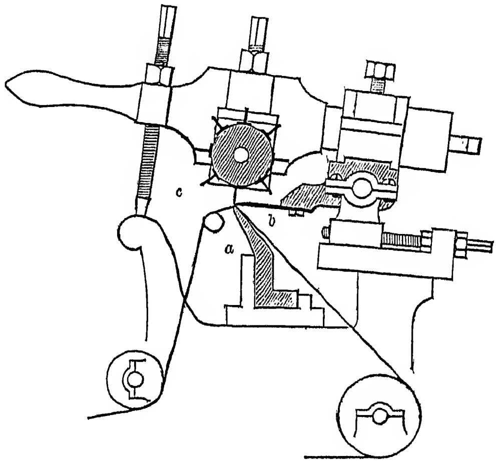
able and above it; the ordinary forms of which three parts are shown in section in the diagram fig. 234.

The roller is carried in a frame hinged or pivotted at the back and lifted by handles at its front ends, to raise or bring the spiral knives down into more or less close contact with the cloth just over the rounded edge of the bed; and the adjustment of the roller above the bed is determined by vertical stop screws, which pass through the handles and rest on portions of the frame of the machine with several small squares of thin paper interposed, one or two of which are taken away

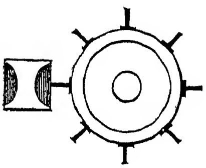
Figs. 233.



234.



235.



to give the final adjustment. The blade is fixed to a piece running the whole length of the frame, called the stock, upon which it can be adjusted to bring its sharp edge into exact contact with the edges of the spiral knives on the roller, and the stock is firmly attached to the under side of the roller frame. The stock also carries the pivots upon which the frame is hinged, so that the stock, frame, roller and blade all move up or down together as one piece; the pivots are held and are vertically adjustable in mortises in uprights with broad bases, called the slots, which pieces are themselves adjustable laterally by screws to vary the distance of the edge of the blade from that of the bed, to accommodate the thickness of the woollen cloth and the extent to which the blade raises

the nap to be cropped between its edge and the edges of the spiral knives on the roller. All these parts are absolutely parallel in the machine by adjustment and individually accurately true, which latter quality is principally attained by the manner in which they are ground.

In the shearing machines made by Mr. Tomlinson at Huddersfield, the rollers are plain iron cylinders from four to twelve feet long and from three to four inches diameter, with collars or flanges at either end, which flanges are pierced with eight or ten equidistant holes for the attachment of the separate helical knives. The latter, shown of their natural size by the section fig. 233, are strips of steel concave at their tee-shaped base to fit the periphery of the roller and are twisted into the spiral form; their ends terminate in round screwed rods which are passed through the holes in the collars, and the spirals are then drawn tight and secured by nuts until they bed truly throughout the length of the roller.

The collected spirals are ground true and cylindrical upon their top edges only and when fixed in their places on the roller. The latter is mounted to revolve between centers in a machine similar to a slide lathe, and the edges are first ground straight with a revolving emery wheel held and traversed in the sliderest. The emery wheel is then exchanged for a fixed grinder, called a *strickle*, a bar of wood about eighteen inches long by three inches square, with concave hollows on two sides which are filled up with emery, fig. 235; the mass of emery formed of alternate layers of glue and of fine grinding emery, after the same manner as the emery sticks used for general polishing. The strickle held in the sliderest is traversed lengthwise and without lubrication to and fro along the roller until the tops of the spirals, under frequent testing with a straight edge, are finished smooth and the angles they form with their sides true and uniform throughout their length. The stock with the blade attached is next held fixed between centers in the same grinding machine, and the edge of the blade is bevilled and then ground straight by a revolving emery wheel traversed in the sliderest. Finally the spiral knife edges and the bevil on the blade are completed or fitted to one another by grinding them together; for this the axis of the roller is mounted parallel with the line of centers upon

which the stock and blade remain as previously fixed, and the bevil is ground sharp by the revolving edges of the spirals which are plentifully supplied with flour emery and oil and revolve downwards upon the bevil or towards the edge of the blade.

Another example of cylindrical grinding is the process of finishing carding rollers used for weaving, wooden rollers covered with the wire cards or fillets which have long replaced the natural grown teasels formerly used for carding or laying the fibres of the wool all in the one direction previously to the spinning. The wire cards are long strips of close stout soft canvas faced with vulcanized india rubber, which carry numerous fine steel wires or *teeth*, about three eighths of an inch high and about the hundredth of an inch in diameter. The steel wire is cut off into lengths, bent into double ended square staples an eighth of an inch wide, and inserted in the carding strip, in a most ingenious automatic machine, with surprising closeness and regularity both as to position and length ; the wider strips called carding cloth, used for the *doffers* or larger rollers, has about 350 and the narrower called fillets for the smaller rollers about 570 projecting wires to the square inch.

The rollers when evenly covered with this material strained and nailed down upon them, are ground cylindrical, as to the length of the wires, against a long emery roller which revolves horizontally with a small reciprocation within the bearings of its spindle. One carding roller is placed to either side of the emery grinding roller, their spindles mounted in horizontal slides of similar character to the machine fig. 232, and the slides at one end of the machine are capable of lateral adjustment towards those at the other, to allow them to carry carding rollers of different lengths. The reciprocation of the revolving grinding roller causes the wires on the revolving carding rollers to ply and vibrate against its surface, whereby their cut off ends are individually rendered smooth and slightly rounded, which is as important as the true cylindrical form of the whole collection of wires. The largest carding rollers are also sometimes ground after the same manner *in situ* in the carding machine, which is so arranged that a grinding roller may be temporarily mounted upon it. A carding roller is sometimes used in the shearing machine fig. 234, to

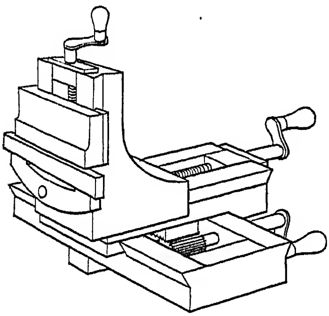
thoroughly raise or *set up* the nap before it meets the knife, but this is exceptional and only used when the surface of the cloth is to be cropped *bare* or all the pile removed.

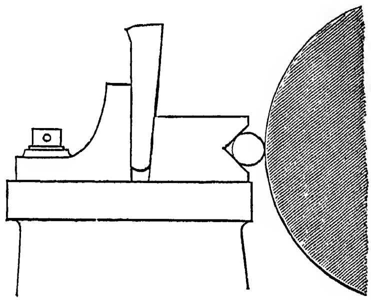
Large natural grindstones running at their usual speeds but without lateral movement are also employed on cylindrical works that are in revolution and reciprocated. In the machines for fettling or removing the marks of the mould and giving a true cylindrical superficies to the parallel portions of the elongated shells for guns, at the Royal Arsenal, Woolwich, a grindstone from 6 feet to 7 feet in diameter and as many inches wide, is mounted to revolve on a horizontal spindle running in fixed bearings, with about a foot of its diameter in a pit in the ground. The cast iron shell is driven between a pair of lathe heads, very much after the fashion of the prong chuck and point of the popit head used in wood turning, and the heads are carried on a slide by which they are advanced to place the shell in contact with the stone, and this slide stands at right angles to and is reciprocated upon a second and long slide parallel with the axis of the stone. The shell revolves at a quick pace driven by a band on the pulley of the lathe head from a long drum on a shaft above, and the stone driven independently revolves in the opposite direction. The hard exterior of the shell is reduced to size, as tested by frequent callipering, and to cylindrical truth by a few traverses backwards and forwards past the edge of the stone; and the action of the one upon the other maintains parallelism and good condition in the edge of the stone.

The grindstone also serves to give a cheap mode of turning, employed for removing the scale and for finishing the forged or drawn iron rods used for bright railings to enclose machinery and other purposes for which smooth and fairly cylindrical bars will suffice. The round rod is presented to the face of the stone in a < groove planed in the front side of a rectangular iron block, which latter lies on the flat horizontal surface of a strong iron support, fig. 237; a rectangular iron bracket, its face parallel with the axis of the stone, is bolted to this table in rear of the loose block and a wedge pressed in by hand between the two advances the block and rod to the

grindstone. The rod rotates in the groove by its surface contact with the revolving stone, and with the wedge slackened it is shifted endwise to grind its length a portion at a time, or, as more frequently, the < groove is planed out to stand at a small horizontal angle to the axis of the stone, in which case the revolution of the latter, together with a moderate pressure of the wedge, causes the rod to continuously travel endwise throughout its length during its cylindrical grinding; the circular grinding marks are removed and the grain laid in the direction of the length of the rods, by subsequently draw-filing the latter and rubbing them lengthwise with emery sticks.

FIGS. 236. 237.





A somewhat similar arrangement is used by the Birmingham gun-barrel grinders who, by manual dexterity and long practice with rather rude appliances, grind the barrels circular, to their taper and to the flats at the butt ends. The grindstone about 6 or 7 feet in diameter is used both for the rough and for the finishing grinding. For the former the operator sits astride a wooden seat or horse, from which he leans over and applies the gun barrel, already bored, across the top of the stone, holding it and twisting it round in both hands one to either side of the stone which revolves from him. To finish and correct this rough grinding, he sits on a stool to one side of the front of the stone, at about the diameter of which there is a horizontal iron slab called the curb, as in fig. 237, and upon this lies a rectangular heavy iron block provided with a concave groove about the size of the barrel in its vertical face, which, with the barrel, is pushed forward towards the stone by a horizontal lever pivotted on the curb. The barrel is held

in one hand and brought into contact with the stone revolving towards it by the lever worked by the other, sometimes it is held still, at others it is allowed to rattle round by its contact with the revolving stone, and the pressure is varied and the work advanced lengthwise across the face of the stone as the correction and finishing grinding proceeds; the circularity and taper thus obtained, the grinding marks are removed by the barrel filer.

Cylindrical rods and the drawn brass tubes used in the manufacture of bedsteads are surface ground and polished between rotating buffs, but also by endless band grinders. In the machines for the first more usual method, two horizontal spindles which are advanced towards one another by screw slides on the top of the frame to accommodate the diameter of the tube, are both placed in rapid rotation by one band running around the pulleys upon them and a large driving wheel below, so that the grinding and polishing buffs they carry revolve in opposite directions, and the tension of the band, as the spindles may be more or less separated, is maintained by a stretching pulley towards the base of the machine. The tube, passed through long hollow cylindrical sockets of rather larger aperture than its diameter, fixed on either side of the machine parallel with and midway between the spindles, as it is slowly traversed lengthwise between the buffs, rotates by their opposing revolution. The grinding and smoothing wheels, 10 or 12 inches diameter by about 3 inches thick, are covered with bull-neck leather, and fed with emery and oil; subsequently the tubes are polished in similar machines by passing between mops or dollies, see catalogue WHEELS, article 67, of about the same diameter, charged with the finer powders, finishing with rottenstone powder moistened with water.

The endless band grinders follow the general construction of their congenors already referred to; in some of them the bands run quasi-vertically and in others horizontally, and the tube entering through a cylinder or other guide on one side of the machine and passing out on the other, usually travels across the faces of several bands carried on one set of spindles, the traverse and rotation of the tube being variously provided for. In a machine patented by Mr. R. J. Edwards, 1885, there are five or six endless grinding bands placed at regular

intervals along the same set of spindles, every such band being double, that is, formed of two bands about two inches wide running nearly edge to edge and provided with separate directing and tension pulleys. The rod or tube entering through a guide, rests on the tops of the peripheries of a series of small wheels, three inches diameter and covered with india-rubber, placed one to either side close to and just below every horizontal grinding band, which supporting or feed wheels are each mounted and driven independently, but are all connected together, so that the axes of all may be simultaneously placed to rotate at a more or less small angle to the line of traverse of the tube. A heavy horizontal lever above every band, pivotted at one end and forked at the other, carries two similarly-covered wheels, about one inch diameter, which turn freely, two on the outer sides of each arm of the fork; the sides of each such pair of wheels close together, their axes in one plane parallel with the traverse of the tube, but slightly separated. The edges of these guide wheels rest on the tube just above the feed wheels below, so that the tube is held between three points to either side of every double grinding band throughout the machine, and the weight of the levers exerted through their freely-revolving guide wheels, suffices to steady and hold the tube which is at the same time rotated and advanced past all the grinding bands by their continual grinding traverse and the friction of the angular rotation of the supporting or feed wheels below it.

The machine is employed for rods and tubes of all lengths of any diameter from one quarter to two inches, which tubes moreover, entering on the one side as left from the drawplate, pass out of the machine on the other smoothed and polished cylindrical ready for lackering. To effect this the bands are charged and fed through hoppers with gradually finer emery powder, ending with crocus and other polishing powders, an unusual arrangement, because it is absolutely essential in all polishing to entirely prevent any risk of the possible admixture of a single particle of a coarser powder with that used next in order. The difficulty in this case is overcome by thin metal partitions which run throughout the frame of the machine and are covered in above, below, and at the ends, so as to entirely enclose and isolate every double band, the apparatus

and the portions of the spindles and shafts appertaining thereto, from its neighbours; the spindles and other parts that extend from side to side of the machine, as also the tube, pass through and work in soft felt packings in the corresponding apertures in the partitions, and every separate enclosure is provided with an exhaust to carry off the spent powders and the metallic dust ground off from the tubes.

The cylindrical rollers used in paper-making machinery, for pressing the single sheet of paper as it is continuously produced, require that the two surfaces should fit each other with great accuracy, in order that the rollers may act uniformly upon the paper, and at the same time from their perfect truth and smoothness, that they may impart a finished surface to it. The ordinary methods of grinding cylindrical surfaces with emery are not sufficiently exact for the completion of these rollers, as the leading source of error in all grinding processes, the unequal distribution of the abrading powder arising from the absence of control, allows the loose emery to accumulate upon the lowest points, and, consequently, after a certain approach to accuracy has been attained, the further continuance of the grinding leads to the depreciation of the surface by the continual introduction of new errors. The impossibility of producing by these means large cylindrical rollers, sometimes required to be more than 6 feet long and 18 inches diameter, with sufficient accuracy to press uniformly a single sheet of the thinnest paper, has led after numerous tedious and expensive experiments to the final abandonment of all abrading powder, and the required accuracy of contact is attained by the simple friction of the surfaces of the rollers rubbing upon each other, plain water being plentifully supplied to lubricate the surfaces and prevent their heating and tearing one another.

The rollers are first turned as truly cylindrical as possible in the lathe, and tested for parallelism by carefully measuring the circumference at various parts with a thin copper wire wrapped around the cylinder, a more exact test than gaging the diameter, the journals of the cylinder are turned at the

same time in order to ensure their being concentric. They are then frequently mounted on their axles and placed in slow rotation in a bath of water in contact with a large wide emery wheel on a spindle precisely parallel with their axes, which in rapid revolution, is slowly traversed to and fro along them to remove the marks of the turning tool and produce a further approximation to truth.

The rollers are next mounted on their bearings in a frame similar to that in which they are to be employed, and their surfaces are carefully adjusted to each other, the bearings of the one roller being fixed, and those of the other placed under the control of a screw adjustment that admits of their being closed upon each other so that the highest points alone just touch. The rollers are now examined to ascertain whether they fit each other tolerably well throughout their length, as when both have been turned in the same lathe they will in all probability possess the same general error, or both be either concave or convex in the direction of their length. More generally long rollers will be turned slightly concave, from the slide of the lathe being more worn in the middle by short works, and if the emery wheel has not been employed the two when placed in contact will show double the amount of error, which if considerable is sometimes reduced by grinding each roller separately with a lead grinder supplied with emery and mounted on the end of a lever, that is used to press the grinder in contact with the surface of the cylinder much the same as in polishing large turned works.

When the errors are so far reduced, that they cannot be detected by the line of light between the cylinders, these are put in revolution, and the one roller is slightly marked with a piece of chalk applied at intervals of a few inches; the revolution of the rollers transfers the chalk lines from the one to the other, at those parts where they touch, which shows at a glance the highest. The points thus indicated are successively reduced with the grinder until the rollers fit each other sufficiently well to transfer all the lines with tolerable regularity, this indicates a moderate approach to general truth, but by no means sufficient for the purpose, as numerous minute errors will still remain that cannot be detected by the chalk lines.

The rollers whether first ground with the emery wheel or only corrected as above described, are now carefully adjusted so that their highest points alone touch each other, and are driven at different velocities, by separate straps leading to pulleys fixed on their axes, which revolve in the *same* direction, so that the two surfaces in contact meet and pass each other in *opposite* directions, and the velocities being different, the relative positions of the rollers are continually changing, and it is only after many revolutions that the same points again come in contact. The friction of the two surfaces causes them mutually, although slowly, to abrade each other, and a constant stream of water is directed upon them, to lubricate the surfaces and prevent them from heating. The latter is a point of considerable importance, as should the rollers become unequally heated from their surfaces being dry, or from too high a velocity being employed, the surfaces would not only be liable to tear, but the irregular expansion of the metal would continually introduce new errors and the true cylindrical form could not result. Attention is also required to keep the rollers in equal contact with each other at the high points throughout their length, and as these are gradually reduced, the rollers are slightly closed upon one another to bring the next series of high points in contact. It being found that if the rollers are firmly pressed upon each other, they are more liable to copy their mutual irregularities, and also that the pressure is liable to cause the one roller to follow the path of the other, or be driven by their surface contact, notwithstanding the action of the belts on the driving pulleys. As the surfaces approach nearer to perfection the length of contact is gradually increased, and proportionately greater care is required in the adjustment of the rollers to prevent the friction becoming so great as to tear the surfaces, or cause increase of temperature. The process is tedious, and requires to be continued for several days, until the contact of the surfaces is as perfect as possible throughout the length of the rollers, in every position in which they are brought, by the continual change of their relative positions. A very smooth and polished surface is produced in this manner by the use of water alone, but for those rollers required to possess a still smoother face, oil is used instead of water for the last

finish, and the smoothness of surface thus gained leaves little room for improvement.

A different method of carrying out the principle of grinding the rollers together with water is sometimes resorted to, in order to allow of their being subjected to the same degree of pressure during grinding that they are intended to sustain when at work, as it is occasionally found that notwithstanding the strength of the rollers they yield slightly beneath great pressure so as to interfere with the accuracy of contact. To avoid this interference, the bearings of the upper roller instead of being suspended over the lower, so that the high points of the two rollers alone touch, are loaded so as to press the two in contact with the same degree of force that is required for pressing the paper. But under this pressure the surfaces in contact do not admit of being driven in opposite directions, because it is found that the two surfaces meeting each other, cause so much friction that the rollers are almost certain to be torn even when a very slow motion is employed. The rollers are therefore driven in opposite directions at different velocities, generally in the proportion of nearly 5 to 6, so that the surfaces in contact travel in the same direction, but the velocities being different they move over each other with a sliding action. The adjustment of the velocity depends principally upon the degree of pressure employed, and the condition of the surfaces; if driven too rapidly the surfaces are liable to heat and tear each other, which in this as in the arrangement previously described is the principal difficulty to be contended with.

The water is supplied through a perforated tube extending the length of the rollers, and should any portion of the surfaces appear to be grinding too rapidly, the action may be checked by stopping up some of the holes to reduce the supply of water at that part, but this is not generally resorted to, owing to the risk of the rollers being allowed to become too dry from neglect on the part of the attendant. The grinding action appears to be principally due to the small particles of cast iron rubbed off by the friction, which serve as the abrading powder. The progress of the grinding may be expedited at the commencement by using the same water repeatedly over again, in order to bring a larger quantity of the grinding

powder into action, but towards the conclusion of the process when the highest finish is required, clear water is alone used.

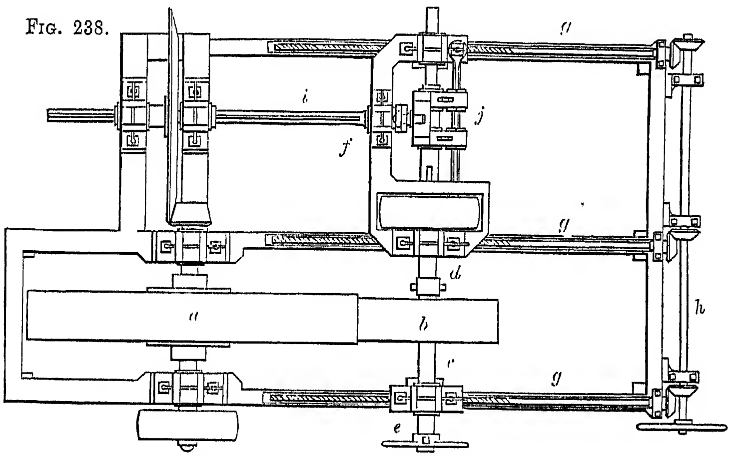
The process appears to be partly grinding and partly burnishing, and does not admit of being indefinitely pursued, as if continued too long the surfaces crumble away; this is also liable to occur if the castings be unsound, and therefore all such places should be plugged up with cast iron of the same quality and hardness as the rollers. Wrought iron is never used for the plugging as it is but little acted upon by the water grinding, and the wrought iron plugs would stand out beyond the general surface of the rollers. Accuracy of surface contact is the object desired, and absolute cylindrical straightness is a matter of secondary importance, the rollers are therefore made simply to revolve upon their axes and are not at the same time traversed through their bearings, as this last would be liable to introduce a new source of error by wearing the journals into a screw-like form. A small amount of end adjustment is however sometimes adopted should the rollers be found to wear into rings; with this view the bearings are so far separated as to allow of a little end motion in the journals, and the insertion of washers between the collars and bearings allows of the rollers being shifted endways a small distance when required. This adjustment is however scarcely called for, as without it, a pair of rollers may be ground so nearly straight that the ordinary test of a straight edge would fail to detect any irregularity, and when three or more rollers are ground with their surfaces in contact, they mutually correct each other for straightness as well as circularity.

The cylindrical rims of driving pulleys are usually turned to form in the lathe, and afterwards smoothed with emery applied on a stick, but in some cases they are wrought into the cylindrical form by the ordinary grindstone, assisted by mechanism, after the same general method as that employed for grinding superior cylindrical works. In this case the grinding is resorted to not from any superiority in the method, but solely from motives of economy, the grindstone being more rapid in its action than the turning tool when the object is merely to produce a level surface, without removing a

greater bulk of the material than is necessary for that purpose. The turning tool requires to penetrate sufficiently deeply into the metal to remove the outer hard crust left in casting, the action of the grindstone is however little influenced by the hard crust, and consequently a much smaller quantity of material has to be removed by grinding to produce the cylindrical form.

In the late Mr. James Whitelaw's machine for grinding pulleys, the grindstone of about 4 feet diameter is mounted in fixed bearings and revolves about 180 times per minute, the pulley to be ground is fixed upon a mandrel parallel with the axis of the grindstone, and makes about 130 revolutions to

FIG. 238.



the minute in the *same* direction as the grindstone, so that when the *opposite* edges of the pulley and grindstone are brought into contact the two surfaces rub upon each other at their combined velocities, and at the same time the pulley is reciprocated a few inches backwards and forwards across the face of the grindstone, to equalise the wear of the latter and ensure the cylindrical form of the pulley.

The machine is shown in plan in fig. 238, in which *a* represents the grindstone, and *b* the pulley to be ground, mounted upon the mandrel *c*, which for the convenience of easy removal is fitted by a key into the spindle *d*, at the one end, and works through a plummer block *e*, at the other. The spindle *d* is

fitted in bearings fixed on the frame *f*, which together with the plummer block *e*, are traversed simultaneously on longitudinal slide bars *g*, by three screws of equal pitch, each communicating by a pair of bevel wheels with a transverse rod *h*, having a wheel on its end to be moved by hand. By this arrangement the pulley admits of being gradually advanced in a parallel line to keep its edge in contact with the stone as the grinding proceeds.

The spindle upon which the pulley is mounted, is reciprocated to and fro through its bearings, by means of a crank on the end of the shaft *i*, which is driven by a bevel wheel leading to a pinion fixed on the axis of the grindstone. The pin of the crank on the shaft *i*, works in a brass that slides in a perpendicular groove in the frame *j*, which is fitted between collars on the spindle carrying the pulley, and slides upon a parallel guide rod at the back. The revolution of the crank pin traverses the frame *j*, and the pulley spindle connected with it, and as the crank pin is fitted in a groove that admits of its being placed at any distance from the center, the amount of reciprocation may be readily adjusted to suit the width of the pulley. To allow of the crank being traversed longitudinally with the frame *f* carrying the spindle of the pulley, the crank shaft *i* is made to slide through the hollow axis of the bevel wheel, which is bored out of the proper diameter and provided with a feather that enters a groove extending throughout the length of the shaft, to cause its rotation.

Mr. Whitelaw employed a second machine for grinding pulleys that are required to be rounded upon the edge instead of being cylindrical, this machine is very similar in its general arrangement to fig. 238, but instead of the spindle carrying the pulley being reciprocated in a straight line through the bearings, the revolving spindle is mounted in a swing frame having vertical pivots. The frame is swung horizontally backwards and forwards by an eccentric, so that the edge of the pulley in contact with the stone describes the arc of a circle of which the vertical pivots are the center, and the latter are fitted into grooves in the top and bottom of the swing frame to admit of adjustment to give any required degree of curvature to the edge of the pulley. The length of traverse of the swing frame is adjusted by attaching the connecting rod leading

from the eccentric, at different distances from the center of motion.

In another machine for grinding cylindrical pulleys, the pulley is mounted on a mandrel revolving with moderate velocity in fixed bearings, and the grindstone which revolves with considerable rapidity is slowly traversed across its face by means of a screw passing through the hollow shaft of the grindstone, and driven by a system of differential wheels mounted on a sliding frame, that is shifted to and fro by hand in order to reverse the motion of the screw. The grindstone is fitted in the center with a cylindrical bearing that slides upon the shaft, and the traverse motion is communicated from the screw by means of a nut having two flanges, that pass through longitudinal grooves in the hollow shaft and are firmly fixed to the cylindrical bearing of the grindstone. The bearings of the spindle carrying the pulley to be ground, are attached to a frame sliding horizontally and adjusted by a single screw to bring the edge of the pulley in contact with the stone; and to keep the pressure uniform notwithstanding any trifling irregularities of the stone, a spring is introduced between the adjusting screw and sliding frame. As in fig. 238, the axes of the grindstone and pulley are placed parallel with each other, and are driven in the same direction so as to combine the velocity of the two surfaces.

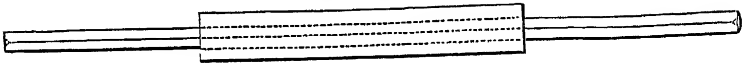
SECT II.—GRINDING INTERNAL CYLINDERS IN METAL.

Internal cylindrical surfaces such as the bearings for spindles and similar works in iron and steel are ground with cylindrical grinders, generally of lead or tin, but sometimes for greater durability and exactness of brass or iron. The grinders are generally solid cylinders of the required diameter, and a succession is employed, each a little larger than the preceding, but sometimes these tools are made with a small power of expansion in order to avoid the necessity for several grinders when the hole has to be materially enlarged.

Figs. 239 to 244 represent some of the most usual forms of grinders for internal cylinders. The first consists of a simple bar of iron, upon the middle of which a lump of lead is cast and turned to the suitable diameter. This form of grinder is

that most generally employed for cylindrical holes that pass entirely through the object; the iron bar upon which the grinder is cast is made much longer than the hole to be ground, in order that it may be traversed endways through the hole to equalize its diameter and prevent the formation of rings. When the hole is long and has merely to be corrected for trifling irregularities, the object is fixed horizontally in the vice, and the central rod of the grinder is grasped in a diestock

Fig. 239.



or fitted with a pulley to serve as the handle. The grinder is then charged with emery, inserted in the hole and worked backwards and forwards with a screw-like motion, the same as in grinding an external cylinder by hand; and to facilitate the first entry of the grinder, it is made slightly taper at the front end. Small grinders soon become reduced in diameter by use, sometimes to compensate for the wear the grinder is laid upon the lathe-bearers or other support, and a few light blows of a hammer are given along one side to spread the metal out to a larger diameter. The two flat faces thus made along the sides of the grinder also serve to allow of the escape of the surplus emery, and with this view large grinders are frequently made with a few grooves along the sides.

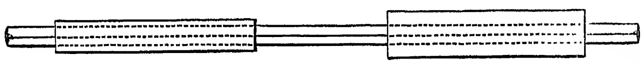
When the hole is so short that it will not serve as a guide, the grinder is mounted to revolve in a lathe and the work held by the hands is traversed endways upon it and at intervals is allowed to be partly carried round by the friction, so as continually to place the work and the grinder in different angular positions, which serve to prevent the hole from being ground either oblique or more on one side than the other. With very short holes, care is required to traverse the work quite square on the grinder, as if it be twisted in the direction of the hole the latter will be ground larger at the ends than in the middle.

In all cases of grinding cylindrical holes there is great risk of enlarging the two ends, partly owing to the work being twisted, and also to the emery cutting more keenly on its first

entry into the hole and becoming crushed before it reaches the middle. This evil is sometimes partly avoided by making the grinder much shorter than the cylinder, the grinder may then be applied to the middle of the hole for a longer period. The grinding of long holes is at all times, however, a process of considerable uncertainty from the absence of any guide for the straightness of the work, and consequently, except for hardened steel, the principal reliance for accuracy is placed upon the boring and broaching tools, and a slight grinding is only occasionally resorted to for the purpose of smoothing the surfaces or fitting cylindrical works together.

Fig 240 is used for grinding two cylindrical holes of unequal

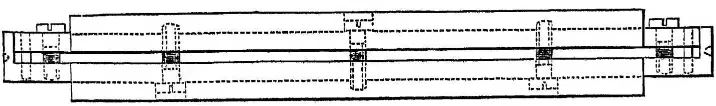
FIG. 240.



diameter on the same line, as in the case of a screw mandrel lathe head, the front bearing of which is usually made of a larger diameter than that at the back, and both are made cylindrical in order to allow of the longitudinal traverse of the mandrel through the bearings in cutting a screw. Both holes are ground at the same time, as the distance between the bearings causes them to serve as a guide to ensure the holes being ground parallel with each other. For the same reason when holes of equal diameter have to be ground for the reception of a cylindrical rod or shaft, the grinder is made sufficiently long to grind both holes at the one process; and in a similar manner when one hole only has to be ground, advantage is taken of any hole in the same line that may be used as a guide, and the grinder is made with a cylinder to fit the second hole, which is not supplied with emery.

The grinder fig. 241 is made in two halves to allow of the

FIG. 241.

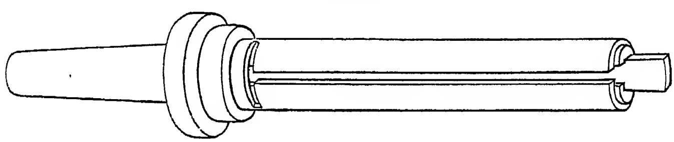


power of expansion, it consists of two semi-cylindrical rods of iron, fitted to each other either by steady pins, or two projections at the end of the one bar, within which the second bar is

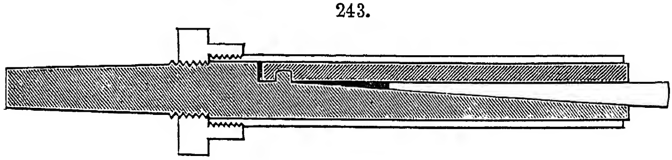
fitted. They are held together by 3 or 4 binding screws, placed at equal distances, passing freely through the one bar and tapped into the other for the purpose of closing the grinder and reducing its diameter. The bars are separated by intermediate set screws, tapped through the one bar and bearing against the opposite. The lead to constitute the grinder is cast upon the bars in much the same manner as for the grinding clamps, fig. 228, two thin slips of wood being inserted between the bars to divide the mould in two parts.

The mould for casting cylindrical grinders is frequently a block of wood bored with a hole of the required diameter, but sometimes a temporary mould is made of a sheet of stout paper wrapped around a cylinder of suitable size and bound with string: the cylinder is afterwards removed. The lead should be only of a moderate heat at the time of pouring or the casting will be liable to be honey-combed or filled with air bubbles even if the mould be quite dry, and if it be damp, the fluid metal may be forcibly driven out. The heat of the melted lead is therefore tested with a piece of paper thrust below the surface, and when it is cooled just sufficiently to avoid burning the paper, the lead is poured into the mould, and when cold the grinder is turned to the proper diameter.

Figs. 242.



243.

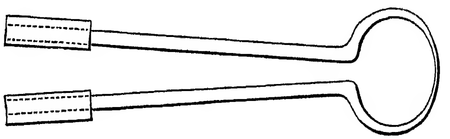


Another adjustable grinder figs. 242, 243 patented by Mr. H. J. Distin, 1889, is employed for the straight tubes of musical instruments and similar long parallel holes. It consists of a cylindrical steel rod which is mounted to revolve in the lathe by the one end, and is divided through the center into two pieces for the greater part of its length. The half

of the rod that is in the solid with the conical end portion held in the chuck tapers along its flat inner face from end to end, and the corresponding flat face of the other and loose half is parallel with the axis of the rod, both are grooved throughout their length to receive a long steel wedge or key, and the shorter is prevented from longitudinal displacement upon the longer half, by a transverse notch which fits a corresponding projection left on the flat face of the latter. The two halves are contained by a thin brass tube slit down one side, the slit terminating close to the end in a transverse mortise that extends around about a third of the circumference of the tube; and the end beyond the mortise is screwed externally and is held in position by a wide ring which screws upon it and on a screw cut on the butt end of the rod. The outside of the split tube is smeared with oil and sprinkled with the emery or other grinding powder and the work is slid over it, after which, and when the grinder is in revolution, the wedge receives light blows from a hammer from time to time to expand the tube to effect and continue the grinding. The work is traversed to and fro and is occasionally twisted partly round upon the grinder in the usual manner, and the slit in the tube permits ample expansion for the limits within which each of several tube grinders are employed, and also serves to retain and more equally distribute the grinding powder.

The spring grinder, fig. 244, is used for short holes in works

FIG. 244.



that admit of being mounted in the lathe, and principally for those holes that do not extend entirely through the work, and therefore do not admit of the preceding forms being employed. The two rods of the grinder when left to themselves spring open like the blades of sheep shears and thus maintain a constant pressure upon the sides of the hole in which they are inserted. For casting this grinder the rods are tied nearly close together with a piece of string and inserted in a smooth metal mould of the same diameter as the hole to be ground,

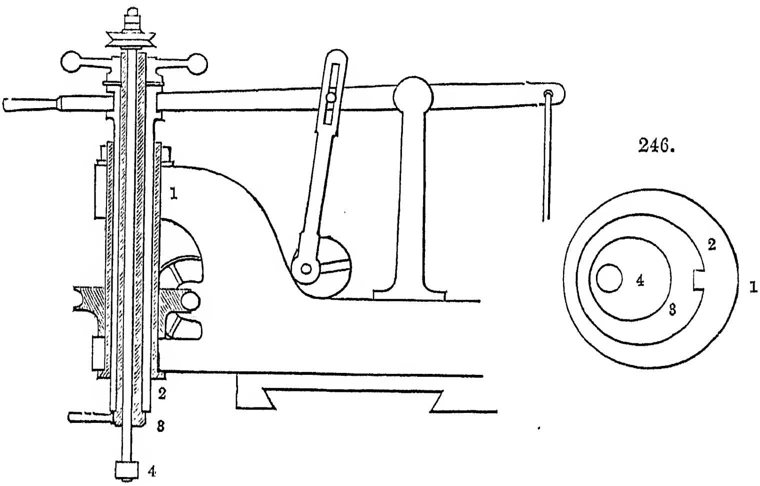
which itself is often used as the mould, as this grinder is usually left from the casting and not afterwards turned; the lead is finally divided lengthways with a saw. The angular manner in which the rods separate is rather objectionable, but nevertheless with careful management it answers moderately well for holes but little larger in diameter than itself, as the angular difference for small openings is so slight as to be scarcely appreciable. A solid grinder is sometimes used for stopped holes, but whatever form of grinder may be employed, it is difficult, with small deep holes, to grind the work cylindrical close up to the bottom of the aperture; the hole is also very liable to become enlarged at the open end, consequently the grinder is always required to be shorter than the depth of the hole to be ground, and to be kept towards the bottom, the amount of end traverse being only just sufficient to avoid the formation of rings.

For holes of moderate length requiring considerable accuracy, the grinder of the same diameter as the required hole is sometimes mounted on the end of a revolving spindle, made to slide endways through horizontal cylindrical bearings under the control of a lever, and the object to be ground is fixed quite stationary. The bearings through which the spindle of the grinder slides are required to be carefully adjusted so as to be quite central and parallel with the axis of the hole, or the latter will be ground either oval or oblique, and the spindle should be somewhat smaller than the grinder to allow of the latter being traversed entirely through the hole to equalize the diameter.

A spindle revolving vertically with the additional power of rotation in a circle capable of enlargement, has been adopted in a machine fig. 245 patented by Mr. R. Peacock, 1887. A headstock travels on a horizontal slide, and the work is mounted on a cross slide upon a second horizontal slide parallel with the first, not shown, to give the mutual adjustment of the work and circular grinder on the lower end of the spindle. A vertical hollow cylinder, 1, shown also in the enlarged plan diagram fig. 246, rotates at a slow rate in bearings in the headstock, by means of a worm wheel fixed upon it which is driven by its screw mounted on the headstock. This cylinder contains a second, 2, which is bored eccentrically and

grooved externally with a keyway from top to bottom, to fit a corresponding feather within and throughout the length of the first, so that the two turn together, but the second cylinder is also free to slide vertically within the first to adjust the depth of penetration of the grinder within the hole. A third cylinder, 3, within the second, also bored eccentrically, carries the grinder spindle, 4, and 3 is fixed after adjustment within

Figs. 245.



and to rotate with 2, by means of a shoulder upon its lower end and a screwed nut hand wheel above which bear upon the ends of the second cylinder. The grinder spindle carries a small emery wheel at its lower end, and is driven independently and at a rapid rate by a small pulley at its upper end.

By this arrangement the emery wheel on the end of the spindle can be placed to revolve concentrically with the driven cylinder 1, or by partially turning the cylinder 3, within 2, its revolving periphery will describe a circle of any dimensions between the difference or the sum of the two eccentricities of 2 and 3, and by very slightly shifting round the cylinder 3, from time to time during the progress of the grinding by the handle at its shoulder below, while the emery wheel is revolving, the hole may be gradually enlarged. The cylinder 2 is raised or lowered within 1, to adjust the depth or penetration of the emery wheel within the work, by means of a long lever which

is enlarged to embrace 2 between collars upon it at its upper end, which lever is moved up and down by hand and is then fixed; or the lever can be kept in oscillation by an adjustable link and revolving eccentric, to give the grinder continuous vertical reciprocation when in revolution within the hole, and a counterpoise weight is then attached to the shorter end of the lever. The headstock can also be traversed along the horizontal slide upon which it stands, for grinding and enlarging the vertical sides of long slots, and circular mortises are ground in like manner, with the headstock stationary, and the work fixed on a plate which is adjustable to give the radius of the arc and moves on a vertical pivot on the cross-slide.

Short cylindrical holes, such as ring gages for measuring external diameters, admit of being very accurately ground by mounting the work to revolve rapidly in the lathe, and applying a fixed grinder of smaller diameter than the hole, held in the sliderest and employed exactly in the counterpart manner to the fixed grinder for external cylinders already described. Sometimes the grinder is made of soft iron or copper, but a circular lump of lead cast on the end of a bar of iron is usually employed; it is mounted in the sliderest which is carefully adjusted as for turning a cylinder, and the grinder supplied with emery is brought in contact with one side of the hole, traversed entirely through it, and gradually advanced sideways to reduce the high points in succession and enlarge the hole exactly to the required size.

Ring gages are more generally first ground out parallel and nearly to their finished diameters, after they have been bored and hardened, with small emery wheels revolving on the ends of spindles running in conical collars in a frame fig. 230, clamped and applied in the sliderest in precisely the same manner as the fixed grinder last mentioned; the steel ring is clamped on the chuck with care that all the binding screws by which it is held exert equal pressure upon it, so that, and notwithstanding its strength in proportion to its size, there may be no risk of its springing back out of shape when released; the grinder revolves rapidly and the ring slowly in reverse directions. The ring gages are finished to size with a succession of cylindrical grinders of lead and antimony of the character of fig. 239, but which are a little tapered at both

ends to counteract the tendency of a strictly cylindrical grinder to enlarge the extreme ends of parallel holes, all of which grinders require very careful and accurate preparation and frequent renewals. The first of these finishing grinders are used with flour emery and oil, and are followed by others with gradually finer and less active or polishing powders to obtain the final diameter.

The cylinders of steam engines and many large works are usually considered to be left sufficiently smooth from such boring machines as fig. 517, Vol. II. Sometimes, however, they are smoothed by grinding with a heavy mass of lead, cast on the middle of a long strong rod, and to the same curve as the inside of the cylinder, which itself in most cases serves as the bottom of the mould. The cylinder is laid on its side and the grinder supplied with emery and oil is traversed backwards and forwards by hand, the cylinder being occasionally twisted partly round so as to bring every portion of its bore successively beneath the grinder.

External and internal cylinders are frequently fitted together by grinding them in contact for the final adjustment. When the works are of hardened steel, they are first separately corrected for the distortion of hardening, and brought so near to the same size that the cylinder will just enter the hole about one-eighth of an inch with stiff friction. A small quantity of the finest flour emery mixed with a little oil is then smeared over both surfaces and the cylinder is gradually worked in, first with a circular motion only, until it has entered about half an inch, and then with a screwing action backwards and forwards just as in grinding out the hole with a solid grinder. A pulley or a double-ended lever fixed on the end of the cylinder serves as the handle. It is necessary to keep the surfaces plentifully supplied with emery and oil, as should they be allowed to become dry they would be liable to heat from the friction, which then becomes so great as to tear the surfaces of the metal, and in extreme cases will even cause them to hold so firmly together that they can only be separated by blows of a hammer applied on the end of the cylinder, to the evident destruction of perfection. The grinding with emery is only

continued until the cylinder will just slide through the hole with uniform resistance; the surfaces are then thoroughly cleaned and worked in the same manner for a short time with oil alone, and again once or twice cleaned, oiled and worked in the same manner, which serves to remove the last traces of the emery and put a final polish on the work.

When one cylinder has to be ground into two holes, as for the bearings of a screw mandrel lathe, the two holes are first corrected with the grinder at the one process, as explained with respect to fig. 240, but the mandrel itself is ground into each hole separately, as a very small amount of grinding suffices to fit the two cylindrical surfaces together when properly prepared; and if the mandrel were ground into both holes at the same time the accuracy of fitting could not be so delicately felt, and in all probability one of the holes would be ground so far larger than the cylinder as to allow of a little side play or shake in the fitting.

Emery may be employed for grinding together works of hardened steel without risk of its becoming embedded in the surfaces of the work, as the hardness of the steel will not allow the emery to penetrate sufficiently deeply to be permanently retained. With soft iron more care is required to entirely remove the last particles of emery, which if permitted to remain would convert the rubbing surfaces into grinders, and they would mutually abrade each other to the rapid destruction of the fitting. For this reason emery is rejected for grinding together brass works, and pumice-stone powder is employed, as from its greater softness and friability it is less liable to become embedded in the metal, and may be washed away with oil. But in all cases the grinding together of soft metals should be avoided as much as possible, and when resorted to the grinding powder should be afterwards thoroughly removed from the rubbing surfaces.

SECT. III.—GRINDING CONICAL SUPERFICIES.

Conical are ground after the same general methods as cylindrical surfaces and with grinders of nearly the same general forms; the principal difference being that as the grinders are conical they do not admit of being traversed

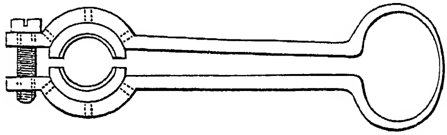
through the work like cylinders to distribute and correct the errors of the grinder itself, and consequently in grinding cones the accuracy of the result depends entirely upon the truth of the grinder, which under the most favourable circumstances transfers nearly all its own errors to the work.

Unlike cylindrical works, conical surfaces are not usually ground for the correction of the trifling errors of turning, partly because they are mostly short in proportion to their diameter and therefore but little liable to spring away from the tool, the principal source of error in turning long cylinders, and partly because the ordinary methods of grinding cones are less perfect than the methods of grinding cylinders, as the conical grinders depend entirely upon the turning lathe for their accuracy. Consequently when the material of the work is sufficiently yielding to allow of the action of cutting tools, the surfaces may be produced more correctly by turning than by grinding, which latter in this case is principally employed for producing accuracy of contact between two cones by grinding them together, and not for improving the general truth of either. Works in hardened steel are necessarily corrected for accuracy of form by grinding, in order to remove the distortion occasioned by hardening; but in this case the cones whether external or internal, are prepared exactly to the angle and only slightly larger in diameter than the required size, by turning them in the lathe while soft, so as to leave but a very trifling amount of correction to be effected by grinding. Internal cones in objects that do not admit of being conveniently chucked, are prepared with the taper broaches, or revolving cutters, described in Chap. XXV., Vol. II., which under proper management produce very accurate and smooth surfaces.

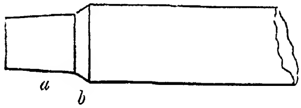
The grinding clamps for cylinders, fig. 228, are also very generally employed for external cones; the grinder is cast in the same manner, in two halves, either upon the cone itself or upon one of the same angle and of a little smaller diameter. The grinder, if cast of the same length as the cone, is liable to round off the smaller end, from this being more constantly exposed to the grinding action, and therefore it is usually made a trifle shorter than the cone. The spring grinder, fig. 247, is also much used for small cones; it is very nearly

a counterpart of the grinder for internal cylinders, fig. 244, the principal difference being, that at the opposite extremity to the spring it is bowed out near the ends for the reception of the grinder, and beyond this enlargement a binding screw is added, for closing it gradually upon the cone, and this at the same time serves to prevent the rods from springing sideways.

Figs. 247.



248.



In grinding the external cone the work in almost all cases revolves in the lathe, and the grinder charged with emery and water is held in the hands. The tool is gradually twisted round to different positions, and continually traversed endways a small distance, according to the length and acuteness of the cone. The object of the short traversing motion is to distribute the emery uniformly and to keep the particles constantly shifting to different parts of the grinder, as if they were allowed to remain in the same position they would be liable to mark the work with rings. On this account also much less force is applied in grinding cones than cylinders, and the grinder is lightly held in an elastic manner so as to permit the emery to roll over between it and the work. At the commencement of the process the grinder should be somewhat smaller in diameter than the required cone, so as to allow for a little enlargement of the former, as well as the reduction of the cone, which latter should at first only enter the grinder for about three quarters to seven-eighths of its length, according to the acuteness of the cone. The abrasion of the two surfaces allows the grinder gradually to advance towards the larger end of the cone, and as this is approached the grinder is from time to time slightly closed, to compensate somewhat for the wear. As the work progresses towards completion, increased attention is required to the condition of

the grinder, and when it becomes so far worn as to mark the work with rings, or that the smaller end of the cone projects through it, a new grinder is cast for the completion of the work.

In the case of two cones of different angles joining each other as in fig. 248, a form frequently employed in lathe mandrels, the grinder cast to a counterpart form is first employed to grind both cones at the same time in order to ensure their being concentric with each other. The long and nearly cylindrical cone *a*, serves as a guide for applying the grinder to the short obtuse cone *b*, which is completed with a grinder fitting both cones, and finally the cone *a* is separately corrected with a single cone grinder.

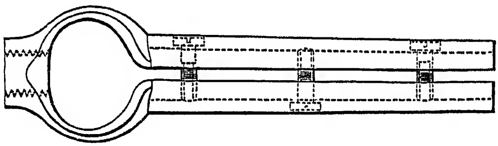
By far the more accurate methods of grinding the external cone are, however, the employment of the end of a fixed grinder, an emery wheel, or the edge of a revolving lap mounted in the sliderest, while the work revolves in the lathe exactly in the manner explained on page 432 for the production of cylindrical surfaces, except that the sliderest is swung round to the suitable angle for the side of the cone. One of these methods is generally resorted to for works requiring the greatest accuracy, as it admits of the cone being corrected with considerable exactness both for angle and straightness of the sides, and the circular section being derived directly from the lathe the adjustment of the diameter is the principal object requiring attention.

The method of a fixed grinder may also be resorted to for grinding the internal cone when the works admit of being chucked in the lathe, and the opening is of sufficient size for the admission of a rigid grinder; but conical holes are seldom so large as to admit of a revolving lap, and extreme accuracy is less frequently required in the preparation of the internal cone because the very minute errors incidental to the ordinary process of grinding, will usually be sufficiently corrected by the final grinding together of the two cones to ensure contact. Internal cones are generally ground upon solid grinders, mostly formed of tin cast upon an iron rod and turned to the corresponding form. The best works are completed with brass grinders which from being harder longer retain their forms unimpaired and therefore leave the holes more accurate.

For short conical holes in small objects such as rings or detached collars, the grinder is mounted in the lathe, generally between centers, and the work is passed over the rod before the screw of the popit head is adjusted, but sometimes the grinder is made as a chuck to screw at once upon the lathe mandrel; this arrangement allows of the work being more readily removed. In either case, the work is applied in just the same manner as for grinding the external cone. The work when small is held in the fingers, and at frequent intervals is allowed to be carried partly round by the grinder so as continually to change its position to compensate for any irregularity of direction in holding it. When the hole is large and the friction is so great that the object cannot be held steadily in the hands, it is fixed in a clamp such as fig. 228, or in the center of a pulley to serve as a handle.

Long conical holes, such as axletree boxes, are sometimes ground upon the spring grinder fig. 249, which may be viewed

Fig. 249.



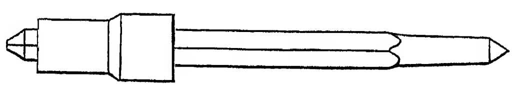
as a combination of figs. 241 and 244, but made to screw directly upon the lathe mandrel after the manner of a chuck, and closed by two or three binding screws; the elasticity of the spring suffices for keeping the halves of the grinder distended, and the work grasped in a clamp with a double-ended lever is applied in the same manner as small objects, the workman standing in front of the grinder, the binding screws of which are gradually slackened with the progress of the work, so as to avoid the necessity for employing more than one grinder.

The conical collars of hardened steel generally employed for the bearings of lathe mandrels, adverted to in the succeeding volume, are required to be made not only as accurately as possible to the same angle and diameter as the cone that is to work within the collar itself, but the axes of both bearings should also be strictly in a line with each other. In the

mandrel the axes of the two cones are placed straight, almost without the possibility of error, by turning both cones in the lathe from the same centers, but a less direct mode is from necessity resorted to for ensuring the straightness of the axes of the two bearings, which are sometimes both made as detached rings or collars of steel, fitted into cylindrical holes in the lathe head; at other times, the mandrel works in a collar and center screw. The parallelism of the holes for the reception of the bearings is obtained by boring both holes at the one fixing, with the cutter bar described at page 569, Vol. II. The collars are turned singly in the lathe to the required hollow cone, but a little smaller in diameter than the finished size, they are then fixed upon a mandrel revolving truly in the lathe, and the exterior turned to fit the holes in the lathe head, the steel collars are afterwards hardened and driven in. This method places the axis of the conical collar so nearly in a line with the second bearing, that the trifling correction necessary for position is brought within the limits of the grinding necessary for fitting the mandrel into the collar, which is effected with a grinder made nearly as a copy of the mandrel, so far as the two bearings are concerned, the one of which serves as a guide for the position of the grinder while the other bearing is being ground.

The mandrels of small lathes are usually made to work at the back end in a conical center, and at the front, through a conical collar the smaller diameter of which is outwards, and consequently in correcting the collar after it has been fixed in the lathe head the grinder has to be inserted from the inside, between the two bearings; the form of grinder usually employed for this purpose is represented in fig. 250. A center

Fig. 250.

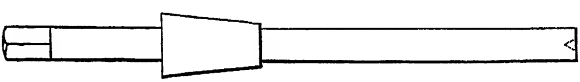


screw having a cylindrical fitting in the back upright of the lathe head, is used for keeping the grinder straight, and the square end of the rod upon which the grinder is cast passes through the conical collar and is received in the square hole chuck of the lathe, by which the grinder is driven; while the

end traverse for advancing the collar lengthways upon the grinder is given by the back center screw, which is supported by the popit head of the lathe employed for driving the grinder. The center screw on which the grinder revolves is screwed into a clamp, fixed on the lathe head being ground, so that the advance of this screw through its clamp traverses the lathe head upon the grinder, which revolves in one position, while the lathe head is shifted to and fro and twisted round at all angles, to maintain a continual change in the relative positions of the grinder and work. Sometimes instead of driving the grinder with continuous motion by the lathe, a pulley fixed on the middle of its stem is used to work the grinder by hand as usual; at other times a cord is wound around the pulley and led to a spring fixed overhead like that of a pole lathe, so as to rotate the grinder alternately backwards and forwards.

Large lathe mandrels are usually made to work through two conical collars in order to allow of change wheels being fixed on their back ends. The two conical collars are mostly ground separately in the first instance, the same as in correcting the cylindrical collars of traversing mandrels. The grinder is then made as in fig. 251, and of tin or brass fixed

FIG. 251.



upon an iron rod, which is turned cylindrically and traverses through a conical plug having a central cylindrical hole that is fitted into the back collar, and serves as a guide for traversing the grinder in a straight line while the front collar is being ground; the back collar is afterwards ground in the same manner, a plug being fitted to the front collar as a guide. The principal errors having been removed with the single cone grinders, the collars are further corrected in the same manner with a grinder having two brass cones, made exactly as a counterpart of the mandrel, and supplied with flour emery and water. Finally the mandrel itself is ground into the collars, first with very fine emery and oil, and lastly with oil alone for the final polish.

When the works are so large as not to be perfectly under control in the horizontal position, or that the weight of the grinder would be liable to cause the lower side of the collars to be ground in excess, the lathe head is placed vertically, and a cord attached to the grinder is passed over a pulley above and led to a counterpoise to sustain the principal part of its weight. By this arrangement the irregularities of fitting in the cones can be more readily appreciated by the sense of feeling, which is mainly depended upon for the condition of the work.

The conical fittings of the plugs and seats of taps and similar works required in large quantities, are first turned to their corresponding tapers and are then ground steam and water-tight in machines. In these the plug usually receives continuous rotation, and the cock is either held at rest and permitted to make intermittent partial rotations, or it is continuously partly rotated first in the one and then in the other direction, in each case to continually vary the relative positions of the one piece within the other to equalize the action of the grinding powders and prevent the formation of rings, as in all circular grinding; and these machines are generally constructed to grind several cocks at the same time, any one of which may be removed and replaced without checking the grinding of the others. A recent machine for this purpose has two lathe bearers, placed some five or six feet apart and parallel with one another, each of which carries a headstock and mandrel at the center of its length. The mandrels project both ways through the headstocks, and carry chucks with pointed centers and jaws at both extremities to support and grip the squares at the larger ends of the taper plugs, the smaller ends of which are supported by the centers of cylinder popit heads fixed at the four ends of the bearers; the whole forming a quadruple lathe. Vertical racks on the ends of a long bar travelling horizontally in guides between the uprights of the headstocks rest on corresponding pinions fixed midway on the mandrels; which bar is reciprocated to rotate the mandrels and plugs first in the one and then in the other direction by an eccentric placed between the bearers, the pin of which works in a long vertical slot in a frame fixed to the center of the bar; the latter also runs on supports and its

vertical slotted frame on rollers, so as to relieve the mandrels of its weight.

The cocks are held in open rectangular frames, the two sides of which are pierced with plain round holes to just easily receive pieces of metal as carriers which are screwed into the bore of the cock at right angles to the conical hole or seat to be ground; and one of the sides of each frame is divided and jointed across the diameter of its hole for more conveniently inserting and removing the work. The transverse end of the frame next the headstock is provided externally with a ratchet wheel fixed to it and bored with a large aperture which fits upon a circular boss on the face of the headstock concentric with the mandrel, and the chuck and pointed center are within the frame. The opposite end of the latter has a plain hole that fits over the cylinder of the popit head, upon which there is a spiral spring which, compressed between a shoulder on the cylinder of the popit head and the end of the frame, presses the work forward during the grinding. The plug smeared with emery and oil is inserted in the cock and the two are placed in the frame, the popit head advanced to give the pressure to the frame, and its center screwed up to support the plug between the jaws and against the center of the chuck. The reciprocation of the bar then causes the plug to continuously make several revolutions, first in the one and then in the other direction, whilst the cock and frame, otherwise stationary, receives a small part of a rotation on the plug, always in the same direction, at the end of every traverse of the bar; effected on the frames on the two headstocks alternately, by ratchets mounted on the latter, and worked by stops fixed on the reciprocating bar at the inner ends of the racks; and the stops are also so arranged as to press each time on the ends of the frames to compress the spiral springs, sufficiently to just relieve the friction of the cock on the plug at the moment the frame is shifted round.

CHAPTER VIII.

THE PRODUCTION OF SPHERICAL SURFACES BY ABRASION.

SECT. I.—GRINDING AND POLISHING SPHERES.

Metal spheres of small and moderate size used for bicycle and other anti-frictional bearings are reduced to their finished form direct from the castings or forgings by grinding. The balls are forged by hand between top and bottom swage tools, in machines between stamps, or prepared between rolls; each roller having one or more lines of hemispherical recesses connected by grooves around its periphery, in all which cases, as also when they are cast, the roughly formed balls are connected together in groups or strings by small intervening pieces of the material. The balls are separated by cutting through these fins, the residue of which, as a preparatory step, is then removed by grinding. When done by hand, the forging or casting is placed in a conical aperture made in the end of an iron rod or holder in the direction of the length of the rod, and is held and twisted about upon an emery wheel or grindstone until the fin has been reduced fairly level with the general surface of the rough ball. This preliminary operation is also effected in machines, generally of a simple character. In one of these the square edged emery wheel employed is reciprocated to about the extent of the width of its edge to equalize its wear, and the frame in which its spindle is mounted is provided with a vertical motion to raise and keep the wheel in contact with the work as the fins are gradually reduced. The balls are held between hollow conical chucks on the ends of revolving mandrels with their fins at right angles to the axis of revolution, which mandrels, and their headstocks stand horizontally, end to end and parallel with the spindle of the emery wheel, one pair to either side of and above the axis of the latter, about halfway up between the diameter of the wheel and the highest point of its circum-

ference. The two mandrels at one end of the machine carry driving pulleys by which they are placed in revolution, and the two at the other end in line with them, slide through their bearings to grip the forgings and revolve by their contact with the work against which they are advanced by levers bearing upon their outer ends worked by a treadle below; with the pressure on the treadle reduced the sliding mandrels are carried back by springs to permit the work to be readily withdrawn and exchanged.

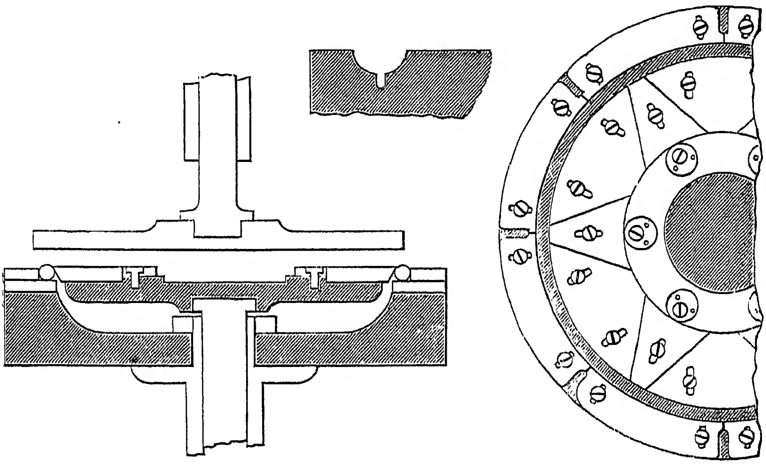
The castings or forgings are subsequently ground spherical and to size between two parallel flat laps which revolve at different speeds, usually in opposite but sometimes in the same direction, or one surface only revolves after the manner described for grinding marbles for children, page 81. The grinding surfaces are either flat emery discs or flat iron plates fed with emery and water, mounted to run horizontally; the spindle of the lower emery disc runs in bearings and on a center below, and that of the upper disc which is supported and descends in the frame of the machine above, is bored throughout its length and through the center of its disc for the admission of the work and the emery and water. The balls roll over and over between the grinding surfaces and find their way outwards towards the circumference of the laps, where they are prevented from escape by a rim or metal casing within which the latter revolves, and the upper disc is gradually lowered as the grinding proceeds until the balls all acquire one size. Iron discs fed with emery and water are employed in precisely the same manner, but they are more often recessed with a series of concentric semi-circular grooves in which the balls are placed before the upper disc is lowered upon them.

In another machine the vertical spindle extends upwards through the lower iron lap fixed upon it, and revolves on an adjustable center below and in bearings above; and the lap is cupped or hollowed out around the spindle to leave it an annular surface, that is turned with the grooves to receive the balls. The upper iron grinding plate, provided with corresponding grooves, is pierced centrally to allow the revolving spindle to pass freely through it, and descends between vertical slides which retain it stationary and parallel with the lower lap

after the balls have been placed in the grooves of the latter. The center supporting the spindle is raised to give the grinding pressure, and the emery and water supplied separately through the fixed upper plate fall into the cupped recess in the revolving lap, from whence they are thrown against the work by the centrifugal force.

A close approach to correct spherical form is obtained by these methods of grinding, notwithstanding that every ball has a tendency to roll principally on one axis parallel with the plane of the revolving plates; this tendency, however, is greatly counteracted by the continually varying contacts of

Figs. 252. 253. 254.



every ball with its neighbours and with the sides of the grooves, which serve to perpetually more or less shift the axis on which it rolls, and without which it would be ground slightly ellipsoidal. The balls also wear and widen the grooves, and to diminish this evil a deep narrow recess is turned in the crown of every semicircular groove, fig. 253, and the four arrises thus possessed by each of the latter attract by far the larger share of the deterioration.

A machine patented by Mr. Chas. E. Gould, of Worcester, Mass., U.S.A., 1890, is arranged to constantly vary the axes of the balls to all directions to more effectually remove the above-named difficulties. The lower grinder shown shaded and in

section fig. 252, is double, and consists of an annular and oi flat circular disc, their surfaces nearly in the same plane, a: the two revolve in opposite directions and at different spee one within the other; the vertical spindle of the inner grind running within the hollow spindle of the outer. The ba rest on the annular surface of the outer disc in a groo formed by that and the edges of segments, together formi annular plates, with which both halves of the compou: lower grinder are covered; the periphery of the central coı pound annular plate being bevelled, so that it bears agair the balls only at a point a little above their diameters. T upper grinder is a plain flat disc, and the spindle by which revolves is mounted to stand a little to one side of, or, out vertical agreement with the axis of the grinder below, hen as it rotates, every point upon its grinding surface is succe sively brought into contact with the revolving ring of ba below, with the effect that the wear on the upper grind serves to maintain its surface perfectly flat and true; while is evident that the differing and opposing rotations of t grinders cause the balls unceasing axial variations.

The annular plates are each made up of numero segments, fig. 254, which are advanced to take up we or to embrace balls of less size. The segments of the out series have vertical edges and radial ends, and are held do by screws which pass through slots into the annular grind below, and they are pushed inwards as they wear away. O or two among them, as shown at the lower part of fig. 254, a rounded off at one end, and these turn upon their bindi: screws at that end as on a hinge to give a temporary openi: to admit or withdraw the balls. The sectors on the inn plate, fixed down in the same manner, are of quasi-triangul shape, and the entire series is advanced to expand the ring circular cams or eccentrics that are held to the plate by scre and bear against the inner bases of alternate sectors, whi latter when pushed outwards by turning the cams with a fork key carry the intervening sectors with them. Harden steel balls when required of great accuracy, are first ground the foregoing machines very nearly to their finished size whil still soft, then hardened and reground to gage, to thus corre and possible distortion from the hardening process.

The accurate glass spheres used in the instruments for recording the duration of sunshine and for many optical purposes, which range from quite small to three or four inches in diameter, are ground and polished by a very simple process which nevertheless secures their absolute truth. The piece of glass first cut and ground to a cube, next has its eight corners ground away to large equal triangular flat facets, the resulting twenty-four pyramidal angles are then similarly ground away and so on, by continual equal reduction of the angles formed, until the original cube becomes a fair approach to a sphere; the piece of glass is usually held in the fingers and ground upon a horizontal revolving iron lap fed with emery or sand and water after the manner of the lapidary, and it is finally rolled or twisted about on the lap with gentle pressure to give it a smooth uniform surface, care being taken throughout not to allow the glass to heat by which it would suffer distortion or might possibly be cracked. When so far prepared the ball is placed in the orifice of a thick copper tube or cylinder, about two thirds of its diameter, the annular edge of which is turned to a true flat internal bevil of about 45°, fixed vertically on the bench; the ball is then continuously rolled about in all directions by the fingers within this annular edge, plentifully fed with emery and water. The grinding first attacks and reduces all the high places on the spherical surface, which, after a time, it reduces to perfect truth; finer and carefully washed emeries are then used for the smoothing, every one on separate similar copper grinders, and the spheres are finally polished within the edges of wood cylinders with putty powder. Glass, agate, and similar substances are thus reduced to true spheres with comparative ease, and the same process may be used for brass and gun-metal, but in these latter a very nearly correct form is first obtained by a different application of the annular cylinders, which as before are of smaller diameter than the required sphere. In such case the metal ball, first turned fairly spherical, is placed in revolution in a conical chuck of the character described page 415, Vol. IV., and a short hardened steel cylinder turned and ground externally at an angle of about 50°, so as to leave it as a very narrow flat annular edge, is held in contact with and rubbed about at continuously varying angles all over its exposed half, acting as a scraper; the

ball itself is also continually released by the fingers or by the tap of a wood mallet and replaced in the chuck to revolve on different diameters, so as to expose all parts of its surface equally to the action of the scraping tool; and when the spherical form is attained the process may be continued, until it is reduced so nearly to its required dimension that it may then be corrected to absolute truth and final diameter by grinding with a metal ring and the powders as already described. It should also be said that the thin annular edge of the *ring tool for balls* is preserved in working condition by carefully rubbing it, held flat, on the oilstone.

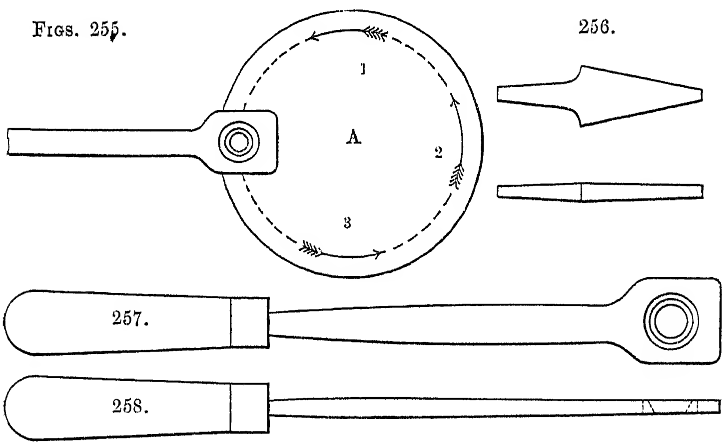
The sphere most widely used, the billiard ball, is generally turned by hand by the method described at some length in Chapter XI. Vol. IV. and when correctly carried out the mathematical certainty of the system leaves nothing to be desired as to results. Failure may however arise from want of diligence or practice, especially when it is considered that the balls must be not only truly spherical but also all of the same diameter, so that towards the termination of the turning there is generally little or no opportunity for correction. Conical ring grinders of brass or gun-metal fed with gradually finer powders and water are sometimes employed, just in the same manner as for grinding glass spheres, for the correction of possible errors left by the turning; and billiard balls otherwise accurate may be reduced all to the same diameter by conducting their final polishing, and prolonging it on the larger, within such rings fed with whiting and water. It should however be remembered that unlike glass ivory is absorbent, and also slightly more so along the length than upon the end way of its grain, and therefore when in the form of a sphere expands from its absorption of the water a trifle more in the one direction than in the other. Hence in all such ring grinding or polishing the rubbing has to be given a little more upon and towards the endway of the grain than in the direction at right angles to it; and without practice and experience this may readily be made to introduce new errors, which, moreover, can only be properly tested and appreciated when the ivory has again become thoroughly dry and has reacquired its natural condition.

The grinding and polishing of spheres in hardened steel,

glass, and other hard substances, after the method invented by the late Mr. Henry Guy, (at that time a workman in the employ of Holtzapffel & Co.,) is perhaps one of the most unexceptionable examples of the production of form by abrasion, as the principle being almost mathematically correct, the true spherical form is certain to be produced under proper management. As in preceding examples, this mode is based upon the section of a perfect sphere being at every part a true circle, and if the ball be previously prepared nearly of the spherical shape, and placed within a circular grinding tool or ring of smaller diameter, so as to bear only on a narrow circular ring, upon putting the ball in rotation equally in every direction, the most prominent points of the ball will be successively reduced until the section at all points is made truly circular, when the perfect sphere will result.

The method of fulfilling these conditions ultimately arrived

FIGS. 255. 256.



at by Mr. Guy was as follows. The grinder is formed of a bar of iron or brass, equal in thickness to about one-third the diameter of the ball, and near the end it carries a conical hole, the sides of which form an angle of about 25 degrees, and sufficiently large to allow about one-fourth of the diameter of the ball to project through the smaller side. The universal rotation of the ball within the grinding tool, upon which the whole method depends, will be explained by the diagram fig. 255, in which A represents a large circular disc supposed to

be revolving in the direction of the arrows. If the ball be placed within the grinder, and carried round in contact with the face of the revolving disc, on the dotted line or thereabouts, the arrows will in every case represent the direction of the rotation of the ball, caused by the revolution of the disc. At 1, the ball will revolve towards the handle, at 2 perpendicularly upwards, at 3, horizontally from the handle, and so on, in fact in every position the axis of rotation of the ball will be the radius of the large disc A, and as the ball is slowly traversed around the disc, the axis of rotation will at every instant be changing in regular succession. Two such discs are employed to rotate the ball, the interval between them being so regulated as to be exactly equal to the diameter of the ball, and they are made to travel at equal velocities in opposite directions. The discs therefore nip the ball, and by their simultaneous action on opposite sides they cause its rotation, notwithstanding the resistance of the grinder.

The two discs are made as wooden surface chucks about 10 inches diameter, quite true on the face, and fixed on two lathe heads that are mounted face to face upon the same frame or bearers, so as to bring the axes of both lathe heads in exactly the same line, with the faces of the discs parallel with each other and at such a distance asunder as will suffice to press the ball sufficiently firmly to cause its rotation. To allow of the ball being firmly held with moderate pressure, the wooden discs are required to be slightly yielding so as to permit the ball to be somewhat embedded in their surfaces to give a better hold. Boxwood is too hard for this purpose, and beechwood answers much better when cut transversely out of large blocks so that the end grain of the wood constitutes the sides of the discs. For polishing the balls, the discs are covered with buff leather. The edges of the discs are turned with grooves of equal diameter for the reception of a catgut band, and in order to ensure the tension being alike upon each, it is better to employ only one band leading from two grooves on the driving-wheel to the two discs, the band being crossed on its path to the one and open on the other, so as to give them equal but opposite revolutions. The more rapidly the discs revolve the quicker the process will be effected, and for grinding metal balls the velocity should not be

less than about 400 revolutions in the minute. Mr. Guy proposed that one of the lathe mandrels employed should have the power of sliding endways through cylindrical bearings, like a screw mandrel lathe, in order that the discs might be kept constantly pressed against each other with uniform force by means of a spring, or a lever and weight; but upon trial this was not found to answer, as the balls were not held sufficiently firmly, and it is better to effect the required adjustment by slackening the holding-down bolt of one of the lathe heads, and advancing that bodily by slight blows of a hammer.

The grinder shown one-quarter size in figs. 257 and 258 is about 15 inches long, the shaft of iron, with small rings of brass inserted in the square enlargement at the end, to constitute the conical grinding surface, which is broached out to the angle of about 25 degrees with the broach fig. 256. The cone of the grinder requires to be frequently restored during use, as much of the truth of the result depends upon the narrowness of the surface contact of the grinder, which should be able to adapt itself readily to the curvature of the ball, notwithstanding that both the ball and grinder are continually changing in curvature and that the ball grinds a narrow spherical seat in the grinder. For a sphere of about one inch diameter, the bearing surface should never exceed about one-sixteenth of an inch wide. Indeed in the first attempts at grinding a sphere by this method, the process failed from a jointed grinder in halves being employed that embraced too large a portion of the sphere, so that perfection could not be attained until the bearing surface was very considerably reduced.

Balls of hardened steel to be ground truly spherical and of definite diameter, are turned while in the soft state as nearly as possible to the spherical form under the test of a ring gage, and are left slightly larger than the finished size, and are then casehardened before they are ground. In grinding they are placed singly within the conical hole of the grinder, a small quantity of oil and emery is then put into the space between the larger side of the cone and the ball, and the discs being put in rapid revolution, the ball and grinder are slipped in between them while they are in motion. The grinder is held horizontally by the handle, and pressed sideways against the

ball to keep the conical grinding surface equally in contact with the ball, which is at the same time slowly but uniformly traversed by the grinder around the discs, within about one inch of their edges, because the further the ball is kept from the center of the discs, the more rapidly it will be rotated.

After a few revolutions of the ball around the discs, the latter become slightly indented with circular grooves, which serve as guides for the path in which the ball is traversed. Care is required to keep the discs pressing against the ball sufficiently tightly to cause its rotation within the grinder, or otherwise, from the surfaces of the discs becoming charged with emery, they will act as laps and grind facets upon the ball. It is also quite necessary that the latter should be constantly traversed around the discs with uniform motion, as should it be permitted to linger for a longer time at one part of the circle than another, the ball would be more ground at that part, and become oval. The necessary supply of emery and oil is given without removing the ball from between the discs, by keeping up the circular motion with the one hand, while a little oil is dropped upon the ball as it revolves, and the emery may be sprinkled upon it in like manner.

The grinding is continued until the ball is made truly spherical, and so near to the required size that upon trial it will barely enter the ring gage, previously prepared of the exact diameter. The final adjustment for size is given in the polishing process, which is effected with dry crocus, sometimes applied on a conical tool of boxwood of exactly the same form as the brass grinder, the revolving discs being covered with leather or cloth. But where great accuracy of size is required, this method is almost too active for the final adjustment, and the method more completely under control, which has been already alluded to, is to polish the balls by rubbing them in all directions with the fingers within a conical brass tool supplied with dry crocus. This removes the circular marks given between the discs, produces a good lustre, and allows of the adjustment for size being effected with almost any required degree of exactness.

Spheres in glass, agate or other hard substances, first prepared fairly round by grinding, as already described in the earlier part of this section, are completed to truth between the

revolving discs held in brass or iron grinders in precisely the same manner as the hardened steel balls, except that water is used with the emery instead of oil. The water is also supplied far more plenteously so as to reduce the heat set up by the friction, which otherwise will sometimes crack glass balls; for the same reason the velocity of the discs is considerably modified. The glass balls are finally polished with a wooden polishing tool, the conical aperture of which is covered with washleather, fixed therein by passing the leather through the hole and straining and securing it by tacks around the margins on the surface of the tool, the leather being fed with putty powder.

SECT. II.—THE PRODUCTION OF THE SPHERICAL SURFACES OF GLASS LENSES.

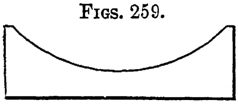
The spherical surfaces of lenses are produced by grinding them in counterpart tools or discs of metal, prepared to the same curvatures as required in the lenses, and employed as the medium for the application of the grinding and polishing powders. The tools are made in pairs, concave and convex, and are first employed mutually to correct each other's errors; as the accuracy of the surface of the lens is principally dependent on the tool upon which it is ground, being accurately formed to the counterpart figure.

For the formation of these grinding tools, a concave and a convex template are first made to the radius of the curvature of the required lens. The templates when of large radius, are sometimes cut out of crown glass by cementing that material upon a bench, and mounting a glazier's diamond upon the end of a light radius bar, sometimes only a rod of wood with a bradawl struck through the rod into the bench, the distance from the diamond to the awl being the radius of the curve. The glass having been cut with the diamond, is separated, the one cut forming the concave and convex edges, which are afterwards ground together with a little emery and water, for which purpose the templates are laid upon the bench and rubbed edge to edge, and one of the pieces is occasionally turned end for end to verify the curves. More generally however templates of large and medium radii are made out of sheet brass; those of long radii are cut with a strong radius

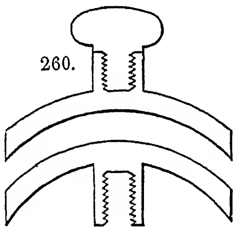
bar and cutter, and those of only a few inches radii are cut in the turning lathe. The brass concave and convex gages are cut at separate operations, as it is necessary to adjust the radius to compensate for the thickness of the cutter, and the brass templates are not usually corrected by grinding as practically it is found more convenient to fit the tools themselves together.

The templates are used for the preparation of the grinding and polishing tools, which for convex lenses consist of a concave rough grinding tool of cast iron, called a *shell*, shown in section in fig. 259, the wooden pattern of which is turned to the curve of the template, and the shell is left from the casting; a similar shell, turned to a radius of about three-eighths of an inch larger than the template, serves as the foundation of the polisher, the preparation of which is described later. For common lenses, that are ground several together, a convex tool of cast iron called a *runner*, of about half an inch less radius than the templates, is also required, as the basis upon which the pieces of glass are cemented, as shown in fig. 261.

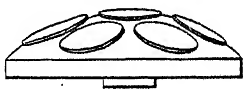
FIGS. 259.



260.



261.



The most important part of the apparatus however is a pair of brass *tools*, one concave, and the other convex, made exactly to the curvature of the templates and to fit each other as accurately as possible. The concave tool is used as the grinder for correcting the curvature of the lenses, after they have been roughly figured in the concave shell. And the convex tool is employed for producing and maintaining the true form of the concave grinding tool itself, and also that of the polisher. The pair of brass tools are represented in section in fig. 260. The backs of the tools are provided with a screw exactly the same as an ordinary chuck, by which they may be fitted on the lathe mandrel to be turned to the curvature of the templates, and by which they may also be attached to the top of

a perpendicular post, about three feet high, strongly fixed to the floor of the workshop and carrying at the top an iron block having a vertical screw, a copy of that upon the lathe mandrel.

The pair of brass tools having been turned to the curvature of the templates, they are next corrected by grinding them together; for this purpose the convex tool is fixed by its screw upon the perpendicular post, and the screw at the back of the concave tool is fitted with a wooden handle of a bulbous form and sufficiently large to be grasped by the two hands. The concave tool is placed upon the convex and the two are rubbed together, first without any grinding powder, to denote by the parts brightened where they bear the hardest, as the manner in which they are ground depends largely upon the nature of the general error to be corrected. Should the tools not fit each other tolerably well, the principal errors are reduced by turning until they agree nearly uniformly throughout their surfaces and touch about equally at the center and margins of the tools, the minute errors are then removed by grinding, which is usually done with emery and water, but as previously explained with respect to the grinding of flat tools for the parallel discs for sextants, it is found that greater accuracy is obtained by using the emery dry. But whether wet or dry grinding be resorted to for the correction of the tools, the emery should be as uniformly distributed as possible by rubbing it level with a piece of glass of corresponding curvature, and any excess of emery around the margin of the tool is wiped off, as there should be rather a deficiency than otherwise near the edges.

The concave tool is then placed upon the convex and worked with a circular swinging stroke, somewhat as in rubbing the hand over the upper surface of a large ball, but instead of the motion being given by the arms alone the body is at the same time swung round, also in a circular path, so as to give a free bold stroke to the tool, but continually varied a little in extent and direction. Between every few strokes the operator moves a little way around the post, so as to continually change the position in which he stands, and gradually to travel round the post. In every position he twists the upper tool partly round in his hands, so as by the com-

bination of the various movements to bring the two surfaces in contact in every possible position and rub them upon each other at all angles. If either at the commencement or during the process of grinding, the tools should be found to bear the hardest near the middle of the curve, the strokes are made short and occasionally varied from the circular path to that of a narrow ellipsis, and the pressure is principally applied vertically; but if the tools bear the hardest near the edges of the curve, long bold circular strokes are taken with the pressure principally sideways. In extreme cases the concave tool is fixed on the post, and the convex tool held in the hands is worked within it, with a swinging stroke, so as to grind the tools at the sides only; but as a general rule, the convex tool is fixed on the post, as the spherical figure may be more conveniently ground in this position.

The determining of the length and direction of the stroke and also whether it should be circular or elliptical, are points that must be left principally to the judgment of the operator, guided in great measure by the sense of feeling; but, speaking generally, it may be said that large circular strokes increase the radius of curvature of the concave tool from the margins being more acted upon than the center; while short elliptical strokes have the contrary effect. The curvature of the convex tool undergoes much less change from the two modes of working, and therefore when it is desired to alter the curvature, the convex tool is first employed to alter the concave tool, and the convex is then fitted to it. The principal object aimed at is to make the tools of the true spherical figure and to fit each other exactly, a small departure from the intended radius being generally far less important than the correctness of the figure.

The glass for the lenses having been selected of suitable quality, it is cut into pieces which are brought to the circular form with flat pliers called *shanks*, the jaws of which are made of soft iron that they may the more readily embed themselves upon the glass and take a firm hold. The pressure of the pliers applied near the edges of the glass causes it to crumble away in small fragments, and the process called *shanking* or *nibbling*, is continued until the glasses are made circular and of a little larger diameter than the finished size of the lenses.

For lenses required in large quantities the molten glass is sometimes pressed into the circular form and to an approach to its surface curvature in moulds, a process adopted to save some portion of the subsequent grinding.

They are next coated on one side with a layer of cement about half an inch thick to form a handle, by pouring the melted cement from a ladle upon the glass in small quantities, as much as will lie on the glass without running off, and as soon as it is set, a further supply is added until the cement forms a hemispherical mass, sufficiently thick to be readily grasped in the fingers. This cement is made by mixing sifted wood ashes with melted pitch, the essential oil of which is absorbed by the ashes, and the adhesiveness of the pitch thereby reduced. The proportions are somewhat dependent on the quality of the pitch and the temperature of the weather; but generally about 4lbs. of wood ashes to 14lbs. of pitch are employed, and the cement if too hard and brittle is softened with hog's lard, wax or tallow.

The glasses are in most cases rough ground separately within the shell, fig. 259, either with river sand and water, or coarse emery and water, until the surfaces are brought nearly to the curve of the shell, rubbed with large circular strokes; and the shell is usually placed within a shallow tray to catch the loose sand or emery thrown off in the grinding. The second side is rough ground in the same manner, the glass being warmed for the removal of the cement handle which is transferred to the other side. The parallelism of the two sides is obtained by observing that the edge of the glass is left of equal thickness all round; and the depth from the one surface to the other at the axis of the lens is gaged by measuring with a pair of callipers with bows opening equally to either side of their joint, the one pair of bows is applied to the center of the lens and the other to a thickness gage, a strip of sheet metal filed in steps to definitely increasing widths.

So far the lenses whether large or small and of the best or common quality are treated alike, but for grinding the glasses to the correct form in the brass tool, and also for polishing, they are operated upon either singly or several together according to their size and the degree of accuracy required. The best lenses for the object glasses of telescopes are ground

and polished singly, while on the other hand as many as four dozen of common spectacle glasses are sometimes cemented upon a runner and ground and polished at the same time. When several lenses are to be ground and polished together, the number must be such as admits of being arranged symmetrically around a central lens, as 7, 13 or 21, at other times a group of four forms the nucleus, and the numbers run 4, 14, 30. Lenses of medium quality and size are however generally ground true and polished seven at a time.

The cement at the back of the lenses is first flattened with a heated iron, and the seven lenses are then arranged with the cemented sides upwards in the concave brass tool, one being placed in the center, and the other six at equal distances around it, very near together but without touching. The cast iron runner is then heated just sufficiently to melt the cement and carefully placed upon the cemented backs of the lenses. As soon as the cement is sufficiently softened to adhere firmly to the runner the latter is cooled with a wet sponge, as the cement must be only so far fused as to fill up the spaces nearly, but not quite, level with the surface of the lenses.

The block of lenses, shown in fig. 261, is now mounted upon the post, and ground with the concave brass tool, fig. 260, in exactly the same manner as explained for correcting the forms of the tools themselves. About six sizes of washed emery progressively finer are employed for grinding the work to the true figure, or as it is called *trueing* the lens, the last size of emery being the fine powder collected after one hour's subsidence as explained in the catalogue, EMERY, article 2—5, which leaves so smooth a surface, that when the lens is held between the eye and the light, it shows a semi-polish. The grinding is continued with every size of emery until all the marks made with that previous are removed, and between every change, the brass tool, the hands and block of lenses, are thoroughly washed, and wiped first with damp and afterwards with dry cloths, to remove every particle of the previous emery, which, without the greatest possible care would be especially liable to lodge in the spaces between the lenses, and might, near the conclusion of the work, become detached and make a scratch that would render it necessary to recommence the grinding.

The lenses have next to be polished; the tool for which purpose is made by warming a cast iron shell, and coating it uniformly about one quarter of an inch thick with melted cement; a piece of thick woollen cloth, such as was formerly used for watchmen's coats, is cut to the size of the polisher, and unless the cloth is old and the nap worn off it is seared with a heated iron, and the cloth is placed on the cement in the polisher and pressed into form by working the brass convex tool within it; the pores of the cloth are then filled up with putty powder prepared as explained in the catalogue, PUTTY POWDER, article 2. The putty powder is generally sifted through lawn, and enclosed in a box having a lid perforated with small holes. It is shaken uniformly over the cloth, and moistened by sprinkling a few drops of water over it; the powder is then worked into the pores of the cloth with the brass convex tool, additional powder being applied until the surface is made quite level, and it is worked quite smooth with the tool; from two to three hours being generally required for making up a polisher of 8 or 9 inches diameter. Kerseymere is sometimes used for small lenses instead of the thick cloth, principally because the face of the cloth being finer it is sooner filled up with the putty powder.

The polisher when completed is placed upon the block of lenses, still fixed on the post, and worked with wide and narrow elliptical strokes, the operator continually walking around the post the same as in grinding. The point requiring the principal attention is the degree of moisture of the powder, which should be only moderate; if too wet, it is apt to run loose upon the polisher, which produces a curdled surface so difficult to remove that when once set up it is generally necessary to return to the fine grinding. If upon the other hand the polisher is allowed to become too dry, that is indicated by the edges of the lenses cutting up the surface of the putty powder, which then works with an unpleasant scratching action that will be immediately detected. The proper degree of moisture is indicated by the putty powder being in a rather stiff saponaceous state, and during the principal portion of the polishing, its surface should present a partially glazed appearance. When the surface becomes almost entirely glazed, a little more water is sprinkled on it; but towards the conclusion

of the polishing less moisture is used and the polisher is allowed to become as nearly dry as is consistent with safety, the glazed appearance then covers almost the whole surface. During the polishing the pressure should be very moderate, or the lenses will partially sink into the surface of the polishing tool and become rounded at those parts of the edges which are unsupported by the neighbouring lenses. This evil may be partially remedied by cutting off a portion of the circumference in the manner alluded to on page 417. But in order to avoid the rounding as much as possible, the more accurate the lenses are required the less the pressure that is employed in rubbing them on the cloth polisher.

The edges are finally ground or turned truly circular and to the diameter to fit their seats, with care that the axis of the lens is in the center of the disc and perfectly parallel with the tube in which it is to be used. To attain this the lens is cemented on a chuck in the lathe and put in revolution, the reflection of any fixed object, such as the bar of a window or a lighted candle, is watched, and before the cement has had time to set, the lens is adjusted until the image appears perfectly stationary notwithstanding the rotations of the lens, which shows the axis of the latter and that of the mandrel to be in one line. The edge is then usually ground circular with a bar of brass, supplied with emery and water, placed beneath the lens and gradually raised by a screw tapped through one end whilst the other rests upon any convenient prop on the lathe frame or bearers for its fulcrum. Large lenses are also ground circular revolving horizontally, the bar is then longer, and is pivotted at one end and pressed against the edge by the other. When the edges are turned cylindrical the lens is cemented and adjusted on the chuck as mentioned above, and if large it has a counterpart disc of metal cemented to its exposed surface to receive the support of the popit head of the lathe; the turning, which, however, is far less general than the grinding, is effected with hard steel tools and files after the manner described a few paragraphs later, occasionally, it is performed with a diamond fixed in a steel stem and traversed by the sliderest, but this is rarely employed as the process is too slow to be commercially profitable. The general

manipulation of the diamond in turning glass will be found in Chapter XII.

Telescope lenses even to the largest are ground both by hand and in machines, some of which latter will be referred to, and all of which as nearly as possible copy the motions given to the tools by hand. M. M. Henri frères of Paris, grind all their lenses by hand, by which process they produced the highly accurate 32-inch lens for the Bishopheim Observatory at Leeds; this was ground with carefully washed sand and water which it is their practice to use in place of emery; the edge was ground circular revolving horizontally.

Concave lenses are ground and polished in the same manner as the convex, except that they are fixed in the concave tools and are ground upon the convex, which, as before mentioned, is always the lower tool when several glasses are operated upon together. Spectacle glasses when of special curvatures are usually ground by hand, ordinary kinds are ground and polished a number together and in a machine in the same manner as circular lenses. Little morsels are then nipped or crumbled off all around their margins to reduce them nearly to their elliptical form, with a pair of pliers called *shakers*, made like a pair of scissors without blades; the glass is pinched by the shanks between the joint and the bows, and the tool is passed all around as with scissors in cutting out a paper oval. The edges are finally ground smooth and to the shape of the frames, the glass held between the finger and thumb, on the peripheries of revolving gritstones or fine emery wheels of large diameter supplied with water; some are then grooved all around their flat edges with angular-edged metal wheels and emery to receive the fine wire of invisible frames; manual dexterity and constant practice are usually alone relied upon to keep the axis of the lens in the center of the oval.

As a rule the curvature of a concave or convex lens is entirely produced by grinding, but various expedients have been tried, one already mentioned being that of casting the glass disc with a hollow or rounded surface, with the view of reducing the amount of grinding otherwise required. Messrs. Wray of Highgate, London, for some time attempted this preparatory shaping with the diamond, but finally abandoned it for turning glass as too slow for profitable use, and they

have of late years turned all their lenses to shape, from the smallest up to about two inches in diameter, in the lathe with hand tools of hardened steel. As the hardness of glass is proverbial, its perfectly successful turning with steel tools appears remarkable; in reality this extreme hardness lies only in the outer skin of the glass, within which, under proper management, the material is perfectly tractable, and it is evident that the following process may be extended to numerous other purposes besides that of turning lenses.

The tools used upon cylindrical and taper edges and for all convex curvatures of the lenses are taper flat Lancashire files from 6 to 8 inches long with rough, bastard, and second cut teeth, see p. 820, Vol. II., followed by parallel flat files 4 to 6 inches long with second cut, smooth and superfine teeth for the smoothing; all of which files, however, are left dead hard and not tempered as for use on metal. The concave curvatures are produced exclusively by round tools similar to fig. 392, Vol. II., varying from quite small to about five-eighths of an inch in width of cutting edge, sharpened to a cutting bevil of from 50° to 55° and untempered, which tools indeed are mostly made by grinding out the remnants of the teeth and shaping and sharpening the ends of the worn-out files. The work revolves in light-running lathes of 3 to 4 inch height of center, which, for practical reasons, are driven by foot treadles at varying but always moderate speeds.

For turning convex surfaces, the flat disc of glass is cemented against the flat surface and within the rim of a chuck screwed on the mandrel, and the file, first dipped in turpentine, is held firmly down on the tee of the handrest as a fulcrum, a little tilted up horizontally on the one edge and inclined forwards in the other direction, so that it lies at angles of about 45° in both directions upon the corner or circular arris formed by the face and edge of the glass, in which position it is steadily pressed upon the latter by the other hand holding its tip. Applied with many repetitions the file, every time first dipped in turpentine, reduces the arris to a corresponding bevel of sufficient width. It is then reapplied after the same manner but more tilted up upon its edge on the handrest, to continue the breadth of the bevel towards the center of the lens and to reduce the greater part of it to an angle of say 30°; and so

onwards, always using a part of the last bevel in making the next and more acute, to obtain a firm hold and also to attack the skin of the glass by its edge, until the surface of the lens receives a rough approximation to its intended curve. The file is then applied to reduce these surface angles *seriatim* and equalize the curve; after which a correct counterpart of the latter made in metal, smeared with a little lampblack and turpentine, is held against the lens to mark the high parts, next reduced in the same manner until the curvature is sufficiently regular for the use of the finer cut files, all dipped in turpentine, to smooth it and leave it in condition for the subsequent grinding and polishing, which is executed in the ordinary manner.

Bevel edges are produced as in the first step for convex surfaces; and cylindrical edges, which in lenses are usually of no great width, are produced by continuing the said bevel along them with continued reductions in the horizontal angle or tilt given to the file. The work is rapidly effected, but with great destruction to the files, the teeth of any of which are completely worn out by much less than a day's work.

For concave surfaces the glass disc is mounted and driven in the same manner but the turning is reversed, that is to say, it is always commenced at the center of the lens and carried thence to the circumference; some of the denser qualities of flint glass, as left from the casting and rolling, possess surfaces both rough and sufficiently soft to allow the turning tool a hold, but others that are harder, and all crown glass, have to be first roughened at the center by a partial grinding for this purpose. The handrest is placed rather above the center and about an inch away from the work, and the tool, first dipped in turpentine, lying flat upon it, sloping slightly downwards and thoroughly supported on both sides by the fingers, much in the same manner as in turning hardwood, is pressed forward against the glass and at the same time moved round on the portion of its shaft which lies on the rest, as on a center, to make a shallow cavity in the middle of the flat surface of the disc. The cavity is then enlarged and deepened by similar strokes, after which, always plentifully moistened with turpentine, it is attacked at its outer edge and gradually widened by repeated similar strokes until it is continued as a

fairly uniform curvature to the circumference of the lens, which latter it may be made to meet in an unbroken and even fairly sharp angle.

The breadths of the cuts vary but rarely exceed a width of half an inch, and the depth is inconsiderable, less than the thirty-second of an inch, to avoid pitting or flaking out small specks from the surface. Recommencing at the center, repetitions gradually deepen and improve the regularity of the recessed curve, but in these strokes and more especially towards the completion of the work, the tool is sometimes presented quite differently; the strokes described are continued, but varied by others made with the tool supported on the side of its shaft, its face quite vertical, and swept round as before on the rest, as on a center, sometimes with the face of the tool and sometimes with its cutting bevil or back towards the circumference of the glass; others again, with the tool presented in the positions last described, make occasional strokes by raising its cutting end nearly vertically from about the center towards the periphery of the disc, effected by depressing the handle, all which variations appear mainly due to individual practice. Towards the completion of the curvature a blackened metal counterpart is frequently applied to mark the high parts which still require reduction, which are then traversed by the tool with lessened pressure; the cutting ends of the tools it should be said are always of considerably less radius than that of the curve to be turned, hence only a minute portion of the edge is ever in contact with the work and the material is removed in the form of moist powder, collected together by the turpentine without the escape of any as dust. The tools require frequent grinding and still more often sharpening on the oilstone, and a constant plentiful supply of turpentine is absolutely essential to obtain their cutting action; to give this latter in the most perfect manner, prior to every cut the tool is dipped in a pot of turpentine and when placed in position on the rest, is first swept around the portion of the curve under operation just out of contact, so that the turpentine running down its shaft to its cutting edge meets and is taken up by the revolving work, and this is immediately followed by the cut made over this same portion.

In turning concaves the glass cuts and is shaped with ease

and rapidity by those accustomed to the work, which, however, requires practice; among other reasons, crown glass is the hardest, flint glass less and less so according to its density, and these varieties, as also different specimens of all, require more or less variation in the inclinations at which the cutting bevil of the tool is held to the work; the surface speed of revolution should also be uniform, hence the advantage of driving the lathe by foot, so that the rotation may be made a little less rapid when the tool is engaged near the circumference than when near the center of the work; beginners therefore find some difficulty, at first even in cutting at all, and for a time in avoiding flaking out or pitting the surface, but to those accustomed to the work all such necessary variations in treatment as above indicated are felt and made intuitively, the quality of the glass being at once detected with the first touch of the tool.

In the late Mr. C. Varley's lathe for grinding and polishing lenses and specula, instead of a fixed post, the lower tools are mounted upon a revolving axis, placed vertically. This considerably expedites the process, which is conducted in exactly the same manner in all other respects, but the necessity for walking around the lower tool is removed. It is however generally considered that the method of grinding lenses of medium and large sizes with a tool mounted on a rapidly revolving axis, is less accurate than when the tool is fixed; and that when circular motion is given to the tool it should be so slow as only to give change of position, leaving the abrasion to be effected principally by the elliptical or circular strokes.

The machine contrived and used by Lord Blythswood, fig. 262, complies with these views and ingeniously copies the motions that are given to the hand tools. The upper concave tool *a*, is a little smaller than the internal diameter of the ring *b*, by which it is surrounded, it has a plain cylindrical edge and rests on the lens which is cemented to the convex fixed tool below. The internal periphery of the ring has three equidistant tapering curved notches, parallel with its axis, which contain true steel balls that are just free when between the larger ends of the notches and the cylindrical

edge of the upper tool; externally the ring b, is mounted in a species of gimbals to the forked ends of two equal arms which extend to adjustable eccentrics, and the axes of these latter and that of the fixed convex tool stand at the corners of an equilateral triangle. The two eccentrics are placed in slow rotation in the same direction by equal bevel wheels keyed on their vertical shafts, one above and the other below equal bevel pinions on the ends of a shaft driven by a speed pulley. The

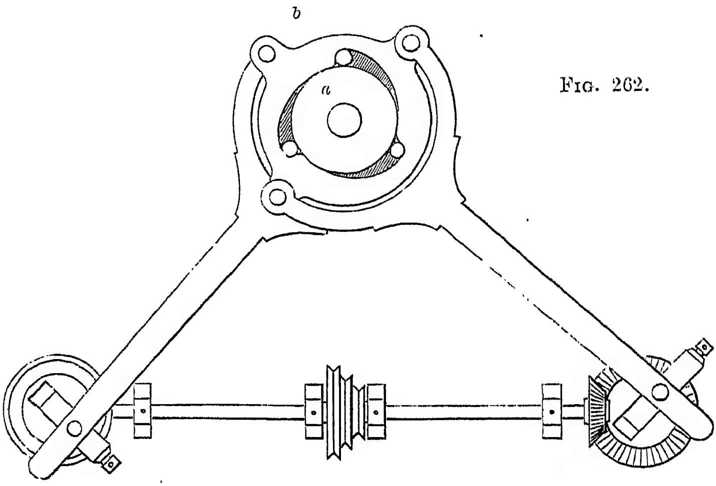


Fig. 262.

arrangement varies the traverse of the upper disc tool a, as that rotates within the ring b; if both eccentrics be thrown out equally every point on the under surface of the upper tool travels in a circular path upon the lens on the fixed tool below, if one be thrown out more than the other, the circuit is elliptical, and if one eccentric be central, the upper tool then traverses in fairly straight strokes; and the upper tool being loose in the ring b, its weight maintains its contact with the work on the fixed tool below. The remaining movement the intermittent but constantly recurring twisting of the one tool round upon the other, given in the hand process by the operator constantly walking round the post, is effected by the balls and notches in the ring b, which momentarily grip and arrest the rotation of the upper tool and alternately release it as it travels round within the ring. With the curved exchanged for true flat discs the apparatus is employed for

grinding flat surfaces, and all the upper tools are provided with central knobs, as in fig. 226, by which they may be lifted out of the ring to supply the abrasive powders or to examine the progress of the work.

In manufactories where large quantities of common lenses are ground and polished, these operations are principally effected by machinery. The block of lenses is mounted upon a slowly revolving axis, placed vertically, and the upper tool is sometimes rubbed across it by hand, the workman remaining in one place, or it has an eccentric motion given to it by means of a small crank fixed on the lower end of a second vertical axis, that is placed a little on one side of the central line of that carrying the work. A pin, fixed in the center of the back of the upper grinding tool enters a socket in the crank, and the revolution of the latter causes the upper tool to describe small circles, which, combined with the slow revolution of the block of lenses, causes every point of the grinder to describe epicycloids upon the surface of the lenses, much the same as in the circular strokes employed in grinding lenses by hand. The radius of the crank admits of adjustment to give various degrees of eccentricity to the upper tool, and the pressure is regulated either by a spring, or by adjusting the weight of the grinder.

The ubiquitous emery wheel has also found employment for the more expeditious preparation of lenses. The machine consists of a strong frame with a long and wide iron bed, true on its surface, with undercut grooves throughout its length for the adjustment and attachment of the different parts. A strong inflexible iron radius bar of oblong rectangular section extending the length of the bed, is mounted parallel with and a little above the face of the latter, and the one end of this bar slides within a short open trough for its first adjustment, after which it is clamped by binding screws in the sides of the trough, and the under side of the trough is provided with a cylindrical pivot, the center upon which the bar oscillates. The pivot is carried by a slide at one end of the bed actuated by two screws, one of which pushes and the other pulls back the slide and the pivot for the finer adjustment of the length of the radius bar, after which the slide is fixed by the opposing action of the same two screws. A

wide flat block fixed to the under face of the other extremity of the bar rests and traverses upon a true horizontal surface, and the butt end of the bar beyond this block is rounded across and travels in contact with the edge of an arc template mounted on the surface, to increase the stability of the bar during its oscillations; and the transverse surface plate with the template may be moved along the bed to accommodate the radius given to the bar and then fixed by bolts in the grooves. The lens is cemented to a surface chuck on a mandrel running in a lathe-head with a wide base, hollowed out below in the direction of its length to allow space for the oscillations of the bar; the lathe-head may be moved along the bed by a traversing screw and fixed down to it by bolts and nuts. The base of a second, the grinding head, is grooved out on its true under surface to a width that will allow it to slide easily along the radius bar and to a sufficient depth to prevent its resting on the bar, that it may not deflect it, and it is fixed to the bar by lateral binding screws in the same manner as the one end of the bar itself is fixed in the pivoted trough; it rests and travels on the before mentioned horizontal surface or, sometimes, on a second similar adjustable surface, two being in that case employed, one for the end of the bar and the other for the grinding head fixed upon it. The spindle with the emery wheel and its driving pulley is mounted in a frame on transverse slides on the top of the grinding head, the vertical adjustment of the edge of the emery wheel, as regards the center of the lens, is given by the center screws of the spindle, and the latter may be placed to revolve vertically or at an angle. For first shaping the lens the spindle and grinding wheel stand at an angle of 45°, and for smoothing a finer grained emery wheel is employed revolving horizontally, the spindle vertical, always plentifully supplied with water. The radius bar is oscillated by an eccentric disc and links and the mandrel and grinding spindle are put in revolution by bands from a drum and pulleys above. When grinding convex lenses the lathe-head stands over the bar between the pivot and the grinder, for concave, the positions of the head and grinder are reversed, and as all the parts are adjustable the lenses may be ground to any radii.

As previously mentioned, the best lenses for object glasses of telescopes are ground and polished singly by hand, in which case, the lens whether concave or convex is kept in the hand and the grinding tool is fixed. The glass if small is held by a cement handle, and if large is cemented to a metal handle, as wood is liable to swell with the moisture. The grinding is performed in exactly the same manner as when several lenses are ground together, but greater care is taken with every successive step, and these lenses are in general polished upon a piece of thick silk, the kind known as lutestring being preferred. The silk cut to the width of about seven eighths the diameter of the lens, is stretched across the middle of the brass tool, and the lens is rubbed backwards and forwards in straight lines along the silk, and instead of the operator walking around the post, the lens is continually twisted around in the hand, and at the same time traversed gradually sideways until the center of the lens is brought to the edge of the silk, when the direction of the traverse is reversed. The single thickness of silk stretched across the tool assumes the form more correctly than the cloth polisher, and the lens is traversed partly off the silk in order that the center may be acted upon equally with the margin. The putty powder and water with which the silk polisher is supplied is kept ready mixed in a corked bottle, to avoid the contamination of dust, and at the time of application the bottle is shaken up and its contents allowed to subside for a few seconds, a small quantity of the water is then taken out with a clean stick and thrown upon the polisher, and thus only the suspended portions of the putty powder are used. The most carefully finished lenses are polished on a pitch tool prepared in the same manner as for polishing specula.

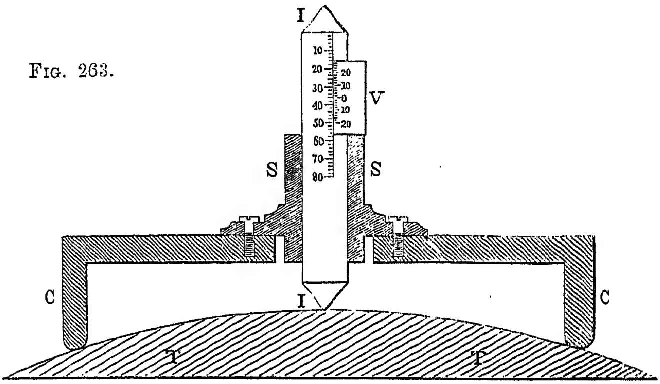
It has been already stated, that with ordinary lenses accuracy of spherical form is of much greater importance than the radius of curvature, but in making the object glasses of achromatic telescopes it is requisite to measure accurately the radii of curvature of the lenses, which are first tried experimentally, and afterwards made as nearly as possible to the radii obtained by calculation, in order to correct the chromatic and spherical aberration.

The late Mr. Andrew Ross, contrived an instrument, called

a spherometer, for measuring the curvature of the grinding tools, fig 263, which he described as follows.

"During a series of experiments instituted by Professor Barlow for verifying his methods of computing the curvatures of an achromatic object glass, in which I was practically engaged, it became necessary to ascertain with considerable accuracy the radii of curvature of the tools on which the lenses were ground. The method then adopted was that of grinding in the tool the edge of a plate of glass, till the edge accurately

FIG. 263.



fitted the tool, and formed what is called a template. This was laid upon a board in which two pins were inserted and the template, guided by the pins, was made to describe an arc of great extent. The chord and versed sine of this large arc being carefully drawn and measured afforded data for calculating the radius, by the well-known formula $2\,R = \frac{\left(\frac{c}{2}\right)^2}{v} + v$, where R is the radius, c the chord, and v, the versed sine. This, though obviously not a very precise method, was sufficiently correct for verifying the theoretical deductions, and it was as accurate as the processes then employed in working the glasses for telescopes."

" With the view of improving these processes, and rendering their results more certain, I have, for more than two years, been carrying on a course of experiments to discover the causes of the discrepancies which were known to exist between theory and practice in this branch of optics. Every improvement in the processes rendered it indispensable to determine more

correctly slight variations in the radii of curvature, to accomplish which I was led to invent the instrument which I now offer to the notice of the Society."—(Soc. of Arts).

"Its principle and general features are explained in the accompanying sketch, where T, T, represents a portion of the convex tool to be measured; and as the tools are of necessity made in pairs we require to measure only one of each. A short cylinder C, C, nearly closed at one end has its edges very accurately turned and ground to a portion of a circle whose radius is known. In the cylinder is attached a carefully made square socket S, S, in which fits and moves the square index bar I, I, the extremities of which are finished with hard steel cones. Upon these conical terminations as centers the circular edge of the cylinder C, C, is ultimately turned and ground, so that all errors of workmanship in fitting and fixing the socket to the cylinder are completely obviated. The index bar I, I, is divided on one face to $\frac{1}{50}$th of an inch, and a vernier V, is secured to the socket by which it may be read to $\frac{1}{1000}$th of an inch, or, by estimation, to $\frac{1}{2000}$th.

"If the edge of the cylinder had been made square instead of circular, then the clear diameter of the cylinder would have been in all cases the value of the chord; but the difficulty of preserving a square angular edge perfectly true, and the different manner in which such a form would lie on spheres of small and large radii, induced me to adopt the circular edge, by which of course the value of the measured chord varies with every change of curvature in the tool." To obtain the value of the radius without determining the value of the varying chord Mr. Ross devised the formula

$$= \frac{v^2 + a^2}{2\,v} - r.$$

a = The known semidiameter, or half the distance between the centers of the small circles which form the edge (which is determined by gently rubbing the cylinder on a perfectly flat surface and measuring the diameter of the ring thus marked on the circular edge).

v = The apparent versed sine as indicated by the vernier.

r = The known radius of the edge of the spherometer.

R = The radius of the tool sought.

Diminutive microscopic lenses, whose diameter is sometimes as small as from one quarter to one twentieth of an inch, are also ground and polished singly, as the radius of curvature is generally too small to allow of several being grouped together. The templates are made as small discs of steel, with slender stems turned in the lathe; for lenses the radii of whose curvature are 5, 10 or 20 hundredths of an inch the diameters of the discs are 10, 20 or 40 hundredths. They are made with square edges and when hardened are applied diametrically as the finishing tools for turning the small metal cups or concave grinding tools. For measuring the diameters of the discs they are applied either in the sector gage, or in one or other of the sliding gages used for measuring the diameter of wire, and graduated decimally for reading the width of the opening, by their verniers, to the hundredth or thousandth of an inch.

The cups when turned are charged with emery and put in rapid revolution in the lathe, which for these minute lenses is generally very small and worked with the drill bow. The lens is cemented with shell-lac upon a small wooden stick and held against the grinding tool with a continual change of angle, the end of the stick being moved in the arc of a circle while it is at the same time twisted on its axis. The same succession of emeries is used as for grinding the larger lenses, but the polishing is usually done with bees-wax hardened with fine crocus, the wax is melted and a sufficient quantity of the crocus stirred in to make it so hard that when cold the finger nail will only just indent it. The smaller the lenses the harder the wax is made, as it should be of such a consistence that with moderate pressure the wax will yield sufficiently to assume the form of the lens, and at the same time be so hard as to retain the figure during the polishing. This composition has also been recommended for larger lenses, but is found to be less suitable than the pitch polisher, as when sufficiently hard to retain its figure the adhesion is too great to be completely under the control of the fingers.

The brass cups for the polishing tools of small lenses are turned in the lathe of a little larger radius than the grinding tool, and the surface is roughened that it may the better hold the wax, the tool is then heated and the melted wax poured in, and when cold is either moulded to the form with

a convex tool, or turned in the lathe, first with a thin scraping tool, and afterwards finished with a circular disc, just as in turning the grinding tool. In polishing the lens the surface of the wax is kept constantly wet with fine crocus and water, applied with a feather, and the lens is held in the same manner as for grinding. To separate the lenses from the runner or handle they are warmed sufficiently to soften the shell-lac, and to prevent scratching the lenses in removing the last particles of cement, the latter is dissolved in spirits of wine.

SECT. III.—GRINDING AND POLISHING SPECULA AND REFLECTING LENSES.

The grinding and polishing of specula for reflecting telescopes requires the greatest possible amount of accuracy and care and is by far the most difficult of all the processes of grinding and polishing for the production of form. The perfection of the refracting telescope is in great measure limited by the difficulty of grinding and polishing the lenses to the correct spherical figure, but an amount of error that would be quite passable in the best lenses, would be altogether inadmissible in the specula of large reflecting telescopes, consequently a very high degree of accuracy of form is essential and at the same time a high polish is of necessity required to produce a reflecting surface. The ordinary difficulties of producing very accurate and highly finished surfaces are also increased by the untractable nature of the alloy of which specula are formed.

Some remarks on the composition of speculum metal have been offered at page 270 of the first volume of this work, and other particulars on the method of casting specula are given in the foot note, pages 371-2, and also in the Appendix, note F, page 462. This interesting subject will be here followed up by some observations on the mode by which the castings, whether of small or large size, are ground and polished to adapt them to the telescope. The process of grinding and polishing specula of small size by hand will be first described, and the application of machinery to the figuration of specula of large and medium sizes will follow.

The hand process is subject to small variations in the practice of different individuals, but these variations are made principally in matters of detail that do not affect the general method, or materially influence the result, and are therefore omitted from the description to avoid unnecessary complication.

In grinding specula by hand, the same general method of manipulation is adopted as for grinding the best concave lenses, that is convex tools formed of the same curvature as the required specula are fixed upon a vertical post, and the work is rubbed upon the tool with circular and elliptical strokes in all directions while the operator continually walks around the post to change the angle of the strokes. The speculum after having been carefully annealed, is attached by the cement made of pitch and wood-ashes to a metal back, to support it during the working, and serve for the attachment of the wooden handle. The back is made from two-thirds to three-fourths of the diameter of the speculum, and its face is made concave to exactly fit the convex side of the latter. The back has a screw in the center by which it can be mounted on a lathe to make the edge of the speculum circular, first by holding a fine file to the revolving edge, and afterwards either a metal grinder supplied with emery, or a piece of blue polishing stone.

A pair of brass templates are prepared to the exact radius required in the speculum, in the same manner as for lenses; but they are more carefully fitted together. The rough face of the speculum left from casting is sometimes removed on a common grindstone, turned nearly to fit the concave template. At other times the speculum is rough ground with coarse emery, on an iron or pewter tool fixed on the post, which grinding is continued until any holes in the surface of the casting are removed, and the face is made quite bright. The smooth grinding is next effected with fine emery upon a convex pewter tool, turned exactly to fit the template. This tool is usually made circular and slightly larger than the speculum, and this smooth grinding is continued with fine emery until the face of the speculum is brought very nearly to the true curve. But however fine the emery may be, it is very liable to break up the surface of the metal into small holes, not-

withstanding the greatest care and, therefore, so soon as the speculum has been brought to a nearly true figure, the smooth grinding is discontinued, to avoid the risk of depreciating the surface.

The face of the speculum is next very carefully ground to a fine surface and to as true a figure as possible, upon a bed of hones which is made of small pieces of either blue polishing stone, or Water-of-Ayr stone, cemented upon a pewter tool with pitch and wood ashes. The stones should be carefully selected as homogeneous as possible, and sawn into blocks about three quarters of an inch cube, the tool is warmed to ensure the hold of the cement, which is then melted and spread uniformly over the surface, the stone cubes are carefully arranged upon the tool in straight lines about one-eighth of an inch asunder, and if the stones are of unequal hardness, it is necessary to scatter the hard and soft pieces as equally as possible in order that the bed of hones may wear uniformly; the stones, however, should not differ materially either in hardness or grain, otherwise the correct figure of the speculum will not be attained. After the stones are arranged in their places and slightly pressed into the cement, the interstices are filled with melted cement to within about a quarter of an inch of the face. The general surface of the bed of hones is then turned very carefully to the curve of the template, and to avoid accident it may be roughed out with the ordinary sliderest into the form of a shallow cone, as the convexity required is very slight.

The bed of hones is used with very little water, and cuts so smoothly that the roughness left by the emery may be entirely removed, and the speculum brought to a very good surface. At the first commencement it appears to act very slowly, but after the principal prominences are reduced it acts more quickly. Great importance in the figuration of the speculum is attached to the proper management of the bed of hones, which is applied with circular and elliptical strokes, exactly the same as the other tools. The late Rev. Mr. Edwards says, the bed of hones should be of a circular figure, and but very little larger than the metal intended to be figured upon it. "If the tool is made considerably larger than the metal, it will grind the metal perpetually into a larger sphere, and by no

means of a good figure, if the metal and tool are of the same size exactly, the metal will work truly spherical, but it is apt to shorten its focus less and less, unless the metal and tool are worked alternately upwards, it had therefore better be made about one-twentieth part larger than the mirror, when it will not alter its focus."

The smoothing with the bed of hones is continued until the face of the speculum is brought to a very true and fine surface, uniformly bright, it is then put into the tube of the telescope and tried as to sphericity and reflection, and any errors of figure that may be thus detected are removed by returning to the use of the bed of hones as often as may be requisite. The surface is made as perfect as possible with the hones in order to leave but very little to be effected with the polisher, as should the polishing be long continued it is liable to depreciate the figure of the speculum.

Specula are polished on metal blocks coated with pitch, or a combination of pitch and resin, materials that are employed on account of their inelasticity. The degree of hardness of the pitch, and its perfect freedom from all impurities, are matters of primary importance. For removing the impurities the pitch is carefully washed with water and when melted strained through linen; it is then thickened by boiling it slowly, until it is of such a consistence that when cold it will just admit of being slightly indented with the finger nail. Sometimes the pitch is hardened by the addition of about an equal quantity of resin, and this compound has the advantage of being less brittle than when pitch of equal hardness is used and is therefore less liable to chip in the polishing. Should the pitch be made too hard it may be softened with a little tallow.

The Earl of Rosse employed resin, melted and mixed with about one-fifth its weight of spirits of turpentine to soften it, which was adopted on account of the difficulty of obtaining the pitch free from gritty particles. But whether pitch or resin be employed, the hardness requires to be adjusted with great care. If the pitch be too hard it will not readily take the figure of the speculum, and if too soft it will not sufficiently retain the figure. In consequence of the different qualities of various samples of pitch and resin, no regular proportions

can be adopted, and the degree of hardness must be decided experimentally in every case.

The form of the polisher is also a matter of considerable importance, as the face of the speculum should be polished, not strictly spherical, but slightly parabolic. Mr. Mudge obtained an approximation to the parabolic form by first polishing the speculum as truly spherical as possible, and at the last finish giving the speculum a few large circular strokes upon the round polisher, so as to increase the radius of curvature near the margin. The elliptical polisher introduced by Mr. Edwards, and first described in the "Nautical Almanack" for 1787, will however give a much nearer approach to the parabolic form without any other than straight or elliptical strokes in all directions. Speaking of the proportions of the ellipse, he says, "for common foci and apertures, viz. from two-and-a-half to nine-and-a-half focus or 3·8 inches in diameter to eighteen inches focus the diameters should be as ten to nine. The shortest diameter of the ellipse being accurately the same as the diameter of the metal, and the longest diameter of the ellipse to the shortest diameter as ten to nine." Mr. Edwards also recommends that for specula having a hole through the center, the polisher should also have a hole through it, of the same size or somewhat less than the hole in the speculum, and he adds, "I have always found that small mirrors without any hole in the middle, will polish much better and the figure will be more correct, if the polisher has a hole in the middle of it."

The Earl of Rosse, among his numerous experiments on the grinding and polishing of specula, tried this form of polisher, and expresses himself as follows:—"The experiments to which I have alluded were made with the elliptic polisher of Mr. Edwards, a contrivance in my opinion possessing more merit than has usually been ascribed to it. I found that a speculum of four inches aperture and eighteen inches radius, after having been polished by hand as truly spherical as I could make it, was invariably improved by working it on the elliptic polisher."

The polisher, generally made of pewter or lead, is turned on the face to the true curve of the speculum, but left rough in order to hold the cement. It is then warmed and the melted

pitch or resin is very uniformly spread over its surface about one-eighth of an inch in thickness, and when the pitch is sufficiently cooled to retain the impression of the finger, the speculum is dipped in water and pressed firmly upon the pitch as in taking the impression of a seal. Owing to the slow conducting power of the pitch, there will be no danger of the speculum being cracked by the heat, if the temperature of the pitch does not exceed about 80 dgrees, although a slight difference in the temperature of any quickly conducting substance, if placed directly upon the speculum, would be almost certain to cause a crack.

When the polisher has been moulded to the form of the speculum, the rough edges are pared away from the margin, and also around the central hole if the polisher have one. The surface of the pitch is then divided into small squares by making grooves quite through its thickness with a heated knife, to allow of the polisher more readily adapting itself to the surface of the speculum. The thickness of the coat of pitch is partly dependent on the size of the speculum, and partly on the hardness of the pitch: the hardness and thickness of the pitch requiring to be so adjusted, that the polisher will always yield to the surface of the speculum so as exactly to fit it during the whole process. If the layer of pitch be too thin, it cannot expand laterally to enable it to ply to the surface of the speculum; and if too thick, it will expand so readily as not to retain the figure. Oxide of iron, prepared as explained under this head in the catalogue, is generally employed for the polishing of specula. Sometimes the oxide of tin is used; but it is considered to give a whiter polish, that is less reflecting. The powder is kept mixed with water in a vial, and applied in the same manner as the polishing powder for lenses; but it is better to employ at the commencement as much of the polishing powder as is necessary for the completion of the polish, and if a further quantity is required it should be applied as sparingly as possible.

The speculum is worked on the polisher with straight or elliptical strokes, the operator continually moving around the post to change the angle. Sufficient pressure must be uniformly applied, to keep the polisher fitted to the face of the speculum. After the rubbing has been continued some time

the polisher and speculum both become slightly warmed by the friction, and if the pitch was originally rather too hard to copy the figure of the speculum perfectly, the increased warmth will soften it and it will then ply well to the speculum, and the polishing will go on satisfactorily; but if the pitch becomes too soft the figure of the speculum will be depreciated and consequently great care is required to maintain the temperature of the polisher as uniform as possible, and just sufficient to keep the pitch in good working condition. Sometimes the polisher is very slightly warmed before applying it to the speculum.

The method of grinding and polishing specula by hand is at all times very difficult and the results very uncertain, even with those of four or five inches diameter; as although it is comparatively easy to figure the specula so accurately to the general form that no errors can be detected by mechanical means, yet, when tried in the telescope, it frequently happens that so many minute errors are presented that the reflection appears quite undefined and in this condition the speculum is unfit for its intended purpose. The principal sources of error apparently inseparable from hand-polishing are, the absence of exact control in regulating the lengths and directions of the strokes, irregular increase of temperature in the speculum and polisher, unavoidably caused by the friction, and also the unequal pressure of the hand. All these difficulties rapidly increase with an enlargement of size, and a speculum of six or eight inches diameter is perhaps as large as can, with the utmost care, be produced by hand of the required accuracy. Larger specula have occasionally been polished by hand; but in the majority of instances it has ultimately proved that the increased incorrectness of defining power, has to a considerable extent counterbalanced the advantages derived from an increase of diameter.

With the view of avoiding the uncertainties of the hand-process, the Earl of Rosse in 1828 constructed a machine for grinding and polishing specula, in which the different motions were susceptible of separate adjustments, and were all under complete control. The machine was subsequently improved and enlarged, so as to be capable of working a speculum of three feet diameter; and from a long experience during which

specula were polished with it many hundred times with great accuracy, it was found perfectly successful in producing large specula with a degree of precision quite unattainable by hand.

The construction of the machine is indicated by fig. 265, and the following particulars are taken from his Lordship's paper published in the Transactions of the Royal Society, 1840: "A is a shaft connected with a steam-engine; B, an

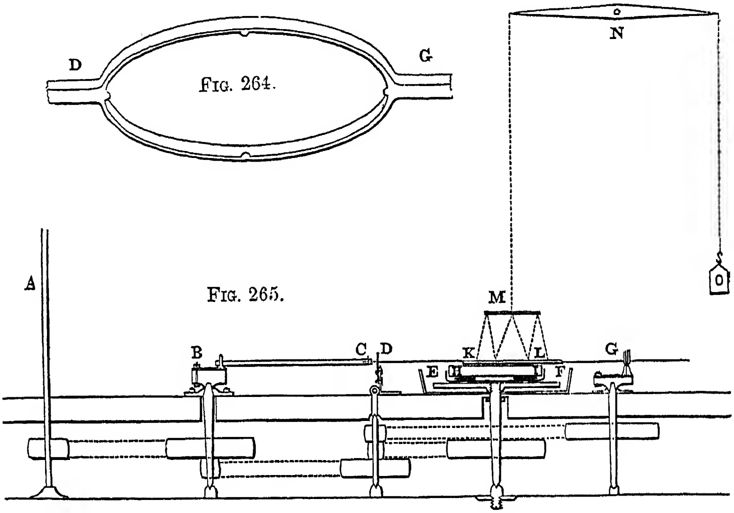


Fig. 264.

Fig. 265.

eccentric, adjustable by a screw-bolt, to give any length of stroke from 0 to 18 inches; C, a joint; D, a guide; E F, a cistern for water, in which the speculum revolves; G, another eccentric, adjustable, like the first, to any length of stroke from 0 to 18 inches. The bar D G passes through a slit, and therefore the pin at G necessarily turns on its axis in the same time as the eccentric. H I is the speculum in its box, immersed in water to within one inch of its surface; and K L, the polisher, which is of cast iron, and weighs about two and a half hundredweight. M is a round disc of wood, connected with the polisher by strings hooked to it in six places, each two-thirds of the radius from the center. At M there is a swivel and hook, to which a rope is attached connecting the whole with the lever N, so that the polisher presses upon the speculum with a force equal to the difference between its own weight and that of the counterpoise O. For a speculum

three feet diameter I make the counterpoise ten pounds lighter than the polisher. The bar D G fits the polisher nicely, but without tightness, so that the polisher turns freely round, usually about once for every fifteen or twenty revolutions of the speculum, and it is prevented by four guards from accidentally touching the speculum, and from pressing upon the polisher by the two guides through which its extremities pass. In fig. 264 this bar is on a larger scale. I have used a variety of contrivances for connecting the machinery with the polisher; but the one I have described is by far the best. The wheel B makes, when polishing a three feet speculum, sixteen revolutions in a minute; to polish a smaller speculum, the velocity is increased by changing the pulley on the shaft A. The machine is in a room at the bottom of a high tower, and doors can be opened in the successive floors, so that a dial-plate of a watch placed perpendicularly over the speculum can be examined at any moment. The dial-plate is attached to a mast, so as to be much higher than the tower, and about ninety feet from the speculum; and a small flat mirror and eye-piece, with its proper adjustments, completes the arrangements for a Newtonian telescope."

The machine is driven by flat leather bands, as shown in the figure, an inspection of which will readily explain the action of the apparatus. The cast iron polisher is used first with emery and water for the grinding, and is afterwards coated with resinous cement for polishing, the intermediate process of the bed of hones not being required. No material difficulty was experienced in grinding the speculum to the spherical form; but some adjustments are required for obtaining the parabolic figure. The elliptical polisher of Mr. Edwards, although so valuable for figuring small specula by hand, was found to fail with larger, from the radius of curvature being increased too rapidly near the edge. Speaking of this adjustment, the Earl of Rosse says:—"Having observed that when the extent of the motions of the polishing machine were in certain proportions to the diameter of the speculum, its focal length gradually and regularly increased, that fact suggested another mode of working an approximate parabolic figure. If we suppose a spherical surface, under the operation of grinding and polishing, gradually to change into one of

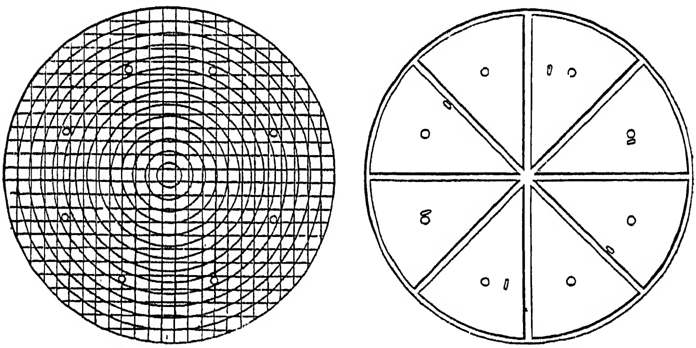
longer radius, it is very evident that, during the change, at no one instant of time will it be actually spherical, and the abrasion of the metal will be more rapid at each point as it is more distant from the center of the *face*. When, however, the focal length neither increases nor diminishes, the abrasion will become uniform over the whole surface, producing a spherical figure. According, however, as the focal length (the actual amount of abrasion during a given time being given) increases more or less rapidly, the nature of the curve will vary, and we might conceive it possible, having it in our power completely to control the rate at which the focal length increases, so to proportion the rate of increase as to produce a surface approximating to that of the paraboloid. Of course, the chances against obtaining an exact paraboloid are infinitely great, as an infinite number of curves may pass between the parabola and its circle of curvature, and it is vain to look for a guide in searching for the proper one in calculations founded on the principles of exact science, as the effect of friction in polishing is not conformable to any known law; still from a number of experiments it might be possible to deduce an empirical formula practically valuable: this I have endeavoured to accomplish."

"The weight of the polisher was constant, being the least possible consistent with its working properly, viz., ten pounds for a speculum three feet diameter."—"The distance of the counterpoising lever would obviously influence the curve; that I have regarded as constant also, viz. twelve feet; as also, in all my most recent experiments the length of stroke of the first eccentric B, which was one-third of the diameter of the speculum; the only variable quantity was therefore the stroke of the second eccentric G. Under these circumstances, the most accurate determination at which I have been enabled to arrive is, that when the stroke of the second eccentric G is such as to communicate a lateral motion to the polisher equal to about ·27 of the diameter of the speculum, the curve will be nearly parabolic." The figure of the speculum is tested during the grinding and polishing, by observing the reflection of the watch-dial, and the adjustment of the length of stroke admits of being made with such accuracy, that the three feet speculum "with its whole aperture, is thrown perceptibly out of focus by a motion of the eye-piece, amounting to less than the

thirtieth of an inch: and even with a single lens of an eighth of an inch focus, giving a power of 2592, the dots on a watch-dial are still in some degree defined."

Much difficulty was experienced in the management of the resinous composition for the surface of the polisher, and the necessity for increasing the thickness of the composition in proportion to the size of the speculum was in itself sufficient to prevent great accuracy being attained. This was first endeavoured to be overcome by dividing the surface of the composition with a heated iron into squares, but although this greatly improved the figure of the speculum by allowing the lateral expansion of a thin layer of the resinous composition, it was found that the spaces soon filled up, and the same

FIGS. 266. 267.



difficulty then returned; but this defect was entirely remedied by dividing the iron disc itself instead of the cement. Several polishers were made on this construction, in which the arrangement and dimensions of the grooves were varied, but the form ultimately preferred is shown in figs. 266 and 267, which represent the face and back views of the polisher. "The circular grooves were turned with the sliderest, and are three-eighths of an inch deep and one quarter wide, leaving bands of continuous surface one quarter of an inch wide. The grooves at right angles are about one inch and a quarter distant, one quarter of an inch wide and half an inch deep, cut with the circular saw."—"The polisher was first truly ground and then the layer of resinous composition applied, the grooves remaining empty." There was still a difficulty

with respect to the hardness of the resinous composition; on the one hand it is essential to the truth of the general figure that the composition should be soft enough to expand laterally to enable it to fit the speculum, on the other the composition is required to be as hard as is consistent with the polishing powder being able to embed itself in its surface, in order that the face of the speculum may be equally acted upon by the polisher notwithstanding minute differences in the texture of the metal at different parts. The Earl of Rosse found that the two properties apparently inconsistent with each other, could be imparted to the polisher at the same time, simply by using the resinous composition of two degrees of hardness, so as to form two very thin strata, the outer one being the harder.

For the preparation of the composition "common resin is melted, and when nearly boiling, spirit of turpentine is added to it, perhaps about one-fifth of its weight; but resin varies so much in quality, that there is no guide except trial. When the mixture has been incorporated by stirring, a cold piece of iron is to be immersed in it, and then placed for some minutes in a vessel of water, at a temperature of 55°; if then a moderate pressure of the nail makes a decided impression without splintering, it is of a proper hardness for the first layer on the polisher, and only requires to be strained through canvas."

"For the second layer, it is mixed with one fourth of wheat flour, which by increasing its tenacity and diminishing its adhesiveness, prevents that accident so much complained of by practical men, viz., the separation of minute particles of pitch from the polisher, which afterwards run loose between the polisher and the speculum. It is to be boiled till the water of the flour has been expelled, and the mixture becomes clear, and the boiling further continued till some of the turpentine has been driven off, and the mixture has become so hard, that at a temperature of 55°, a very strong pressure of the nail makes but a slight impression: it is still too soft, and I then add to it an equal weight of resin; it will then be hard enough to produce a very true surface and at the same time, soft enough to suffer the particles of polishing powder to embed themselves, and consequently to produce a very fine black polish. Whenever the resinous mixture is remelted, I suspend the

vessel to the beam of a scale, counterpoise it, and take care to apply the heat so gradually as not to drive off any of the turpentine, which is immediately perceptible by the disturbance of the equilibrium."—"To apply the resin, the polisher is first heated to about 150° and the soft mixture laid on with a large flat brush, to the thickness of about one-thirtieth, or one twenty-fifth of an inch; it is then suffered to cool to about 100°, and the hard mixture applied in the same way and to about the same thickness. When the temperature has sunk to 80°, the polisher is placed on the speculum previously covered with peroxide of iron and water, of about the consistence of thin cream."

The Earl of Rosse found that the quality of the polish which yields the maximum of defining power is that technically called a black polish, provided a very fine grain is perceptible when the speculum is placed near a window. A speculum may be polished so that its surface appears without grain like quicksilver, but it is necessary for this purpose to employ a softer resinous cement than appears consistent with a very true surface, and the Earl of Rosse considered the best chance of improving the polish would be to search for some polishing substance consisting of smaller particles than the fine peroxide of iron, so as to produce a grain not exceeding the magnitude which theory has assigned as that of an undulation of light. As shown in fig. 265, the speculum revolves face upwards within the water cistern E F, and this cistern being nearly filled with water kept at a temperature of 55° no unequal expansion of the speculum from increase of temperature can take place, and the pitch being also maintained at the same temperature as that at which it was first adjusted, does not become softened during the polishing as in the hand process.

In grinding and polishing the gigantic speculum of 6 feet diameter, the Earl of Rosse employed the same general arrangement of apparatus as that used for the 3 feet speculum; but from the increased dimensions, some modifications were required. In figuring the 6 feet speculum, the circular grooves in the cast iron polisher were omitted, and the straight grooves at right angles were made about 1 inch deep and 2 inches asunder, so as to divide the surface into squares. The weight of the polisher was uniformly supported at twelve

points, the piece M, fig. 265, being made triangular, with a pulley at each corner; a cord was passed over every pulley, and each end of the cord supported the middle of a straight lever, the ends of which were attached to the polisher. In the rough grinding, the great weight of the iron disc, and the brittle nature of the speculum metal, rendered the placing of the grinder upon the mirror highly dangerous, as the slightest jar of the grinder upon the speculum would have been liable to break the latter. To avoid this risk, a number of thin wooden wedges were placed upon the margin of the speculum; the polisher was slowly lowered upon the wedges, and then, by degrees they were gently withdrawn.

In the machine shown in fig. 265, the bar, D G, passing through the fixed guide, D, at one end, and through the revolving guide, G, at the other, communicates a slow lateral motion to the grinder, alternately to the right and left. "But as, in the ordinary crank motion, the duration of the strokes at the extreme right and left would be too great, the wheel on the spindle of this grinding crank is elliptical, the proportion of its axes being about three to one; its angular motion is, therefore, unequal; and the strokes are thus made to dwell a shorter time near the extreme right and left, and a longer time near the center."

In the polishing, it is found that not only should the temperature of the air in the room be maintained nearly uniform during the process, in order to prevent the irregular expansion of the speculum, but also that it is essential that the degree of moisture in the air should be such, that the wet polishing powder should gradually dry at the proper rate. The polishing is therefore not attempted when the air in the room is too damp, and should the air be too dry, it is moistened by a jet of steam. After the process has been continued about eight hours, the polisher is removed, and a fresh application is made of the polishing powder mixed with "ammonia soap," a substance formed by treating common soap with ammonia. This dries more rapidly than the powder mixed with water alone, and the polishing is continued until the surface of the metal is very nearly dry, the process is then considered to be completed, and the polisher is taken off the speculum to allow of its inspection.

Dr. Henry Draper of the University of New York, who has employed a machine of the character of fig. 265 for grinding and figuring specula, records the following interesting experiences. In the course of grinding a speculum of 15 inches diameter it became necessary to remove some blemishes, eight hundredths of an inch deep, which appeared in the otherwise perfect concave face of the metal. To avoid the tedium of doing this entirely by grinding, the defects were carefully stopped up with a thick hard cement of Canada balsam dissolved in alcohol, and a rim of wax being built around the margin of the mirror, the dish thus formed was filled with nitro-hydrochloric acid which quickly corroded away all the unprotected surface to the level of the depth of the imperfections, after which the grinding was recommenced. As regards the invariable risks attending speculum metal, he mentions that a speculum 15 inches diameter when finished and in use in the winter of 1860, was split into two pieces by the expansion in freezing of a few drops of water which had found their way into its cell. He says,—"An attempt was also made to assist the tedious grinding operation by including the grinder and mirror in a Voltaic current, making the speculum the positive pole, by decomposing acidulated water between it and the grinder and thereby oxidizing the tin and copper of the speculum; the operation was much facilitated, but the battery surface required was too great for common use. If a sufficient intensity was given to the current, speculum metal was transferred without oxidation to the grinder and deposited in thin layers upon it. It was proposed at one time to make use of this fact and coat a mirror of brass with a layer of speculum metal by electrotyping, and the gain in lightness would be considerable." This proposal however was abandoned in favour of silvered glass specula, the construction of which is described at the end of the present section. In grinding and polishing both metal and glass specula Dr. Draper invariably follows the late Mr. Andrew Ross' method, see catalogue, Emery, article 4, of using powdered gum arabic in the elutriation of all the finer emeries.

In the figuration of small specula by hand, the metal is usually attached by cement to a temporary back, which serves as the support during the grinding and polishing and is removed before the speculum is placed in the telescope, but even with small specula there is always some risk of distorting or breaking the speculum in the act of detaching the back, and it is therefore at all times the better practice to form the back in such a manner that it may remain permanently attached to the speculum, and constitute its bed in the telescope. Larger specula, unless uniformly supported at all times are liable to flexure, which would destroy the accuracy of figure given by grinding; it is therefore of the first importance that the larger specula should be ground and polished in the same bed that is to be employed in the telescope.

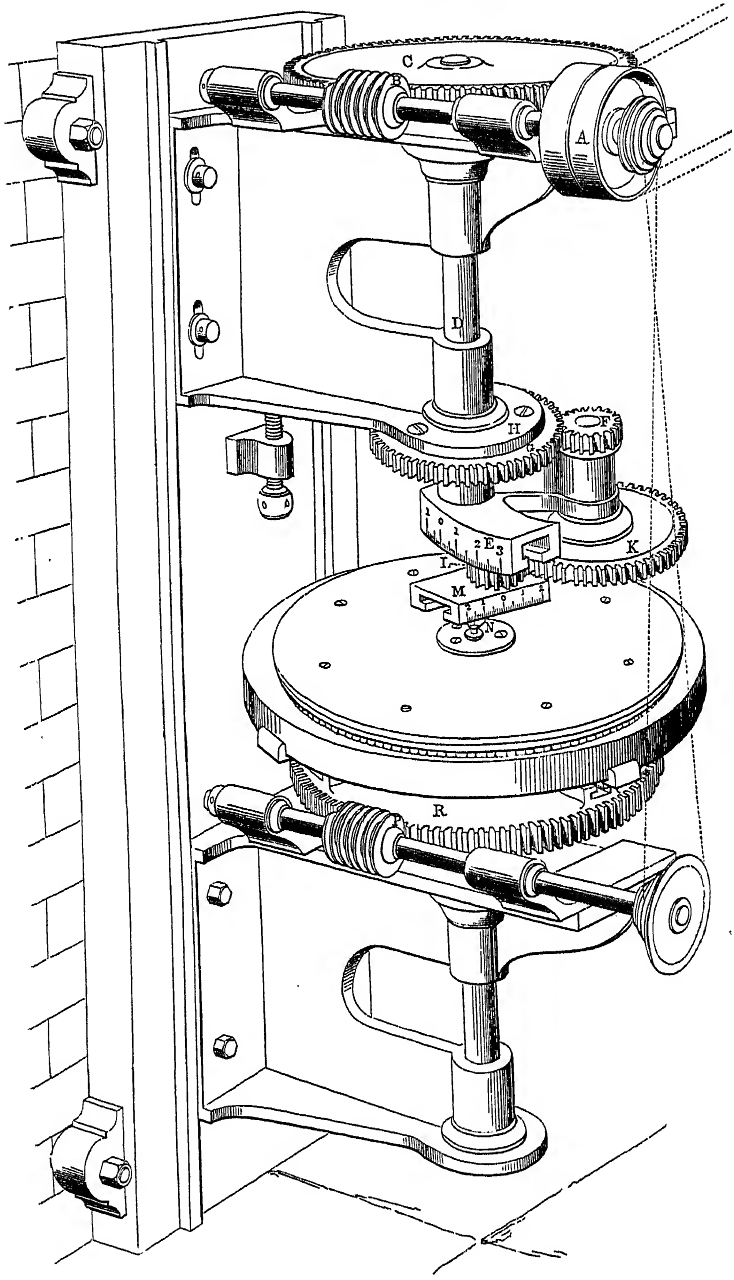
To prevent flexure in specula of moderate dimensions, the Earl of Rosse found it quite sufficient to support them in their box on three strong iron plates, each plate being one-third part of a circular area, the same size as the speculum and a sector of it; the plates rest at their centers of gravity on points fixed at the bottom of the box of the speculum, and therefore no flexure of the box can affect the latter. In supporting the speculum of 3 feet diameter, Lord Rosse used nine plates, every group of three being supported at their centers of gravity upon a triangle, having three points to sustain the pressure, and the center of every triangle is supported upon one of three points in the bottom of the box. The 6 foot speculum is supported in a similar manner upon twenty-seven cast-iron plates, sustained upon a series of nine triangles, that are again supported upon three triangles, the centers of which rest upon three points. The twenty-seven plates were originally attached to the speculum by felt and pitch, but when the telescope was placed at different inclinations, it was found that the reflection was distorted, owing to the speculum having a slight motion edgeways, which threw some of the points of bearing partially out of contact. This difficulty was overcome by removing the layer of pitch and felt by which the plates were attached to the speculum, and substituting sheets of tin, which allow the speculum to slide a small distance upon the plates.

A very valuable machine of a different construction for polishing specula, was contrived by Mr. William Lassell, of Starfield, near Liverpool. This gentleman devoted many years to the construction of reflecting telescopes, and his success in figuring specula of all sizes, up to 9 inch diameter and 9 feet focal length, by hand, led him to conceive the idea of constructing a telescope with a speculum of 2 feet diameter and 20 feet focal length. As a preliminary step to the construction of the speculum, Mr. Lassell inspected Lord Rosse's laboratory, and the performance of the machinery for grinding and polishing specula appeared so satisfactory, that Mr. Lassell determined to employ a similar machine for polishing his 2 foot speculum. "But finding, after many months' trial, that he could not succeed in obtaining a satisfactory figure, he was led to contrive a machine for imitating as closely as possible those evolutions of the hand by which he had been accustomed to produce perfect surfaces on smaller specula." The idea of the machine was communicated by Mr. Lassell to his friend Mr. James Nasmyth, of Patricroft, near Manchester, by whom the mechanical details were designed; and the machine was constructed on the beautiful arrangement shown in fig. 268, which is copied from a drawing kindly supplied by the late Mr. Nasmyth, who also wrote the following description for these pages.

"The power is conveyed, in the first instance, by a band or belt, to the pulley A, which conveys motion by the endless screw B, to the wheel C. The spindle of the wheel C, viz., D, has made fast to it, a crank, or arm, E, which carries a pinion F, and causes the pinion to revolve round the toothed circumference of the wheel G, which wheel G being fixed to the bracket H, causes the pinion F to revolve with as many turns as its circumference is less than that of the wheel G, viz., 5 to 1.

"As the spindle of the pinion F, has a wheel K, fixed to it at its lower end, this wheel K will, in like manner, convey motion to the pinion L, which works on an adjustable center pin, and as the T groove in which the center pin of L works, is radial to the center of the wheel K, this pinion may be set to any degree of eccentricity, and yet be in gear with K. It will also be seen that the pinion L has a cross crank, M,

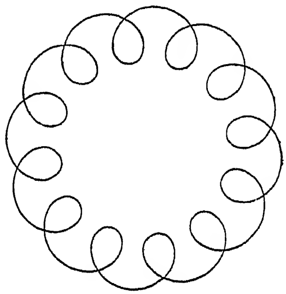
FIG. 268.



attached to its under side, which, having its crank pin, N, also sliding in a T groove, it may be set to, and fixed at, any degree of eccentricity, so that we have by these two eccentric movements the means of giving to the pin N, any compound motion we require.

"The polisher is of wood, or other suitable material coated with pitch, and divided into squares. This polisher is free to move upon the pin N, while N causes the polisher to slide over the surface of the speculum with a motion somewhat like that shown in fig. 269. In order to cause every part of the surface of the speculum to continually change its situation with respect to the movements of the polisher, it has also a slow revolving motion given by an endless screw, P, pitched or working into the teeth of the wheel R, which forms the base on which the speculum rests, while receiving the action of the polisher.

FIG. 269.



"The speculum rests on nine equilibrium points so that each ninth of its body is made to rest on a point or surface placed under the center of gravity of each ninth of the speculum surface, and so avoid all risk of distortion. It is the best practice to polish the speculum while resting in the cell in which it is to be when actually in the telescope, so as no risk of distortion may occur, as would be the case were it removed, after polishing, into another cell or bed. By means of this admirable machine, a speculum having a decidedly hyperbolic figure may be corrected and brought to a perfect parabola, or to a spherical curve, or the same may be done in the reverse order at pleasure. A stronger proof of the perfect capabilities of Mr. Lassell's machine could not be given."

From the foregoing description it will be seen that the essential difference between the machines contrived by Lord Rosse and Mr. Lassell, is that in the former, the polisher is traversed over the speculum with reciprocating longitudinal motion, and in the latter, the polisher has a continuous epitroithoidal motion, the path of which is dependent upon the

adjustments of L and M. Mr. Lassell's polisher was made of two thicknesses of pine wood, with the grain crossed; this, from its lightness, did not require to be counterpoised, and apparently from its being sufficiently yielding to accommodate itself somewhat to the form of the speculum, a single coating of pitch was found sufficient, and the polishing was completed with wet powder. Very complete evidence of the perfection of the speculum polished in this machine is afforded by the circumstance, that with the telescope to which it was fitted, Mr. Lassell discovered the satellite of Neptune, the eighth satellite of Saturn, and re-observed the satellites of Uranus, which latter, since their announcement by Sir W. Herschel had been seen by no other observer.

In Dr. R. Greene's machine for grinding and polishing specula and lenses, the polisher is mounted on a very slowly revolving axis, and the speculum also revolving slowly but at a different rate, is traversed over the polisher by means of a central pin, joined to the extremities of two horizontal connecting rods at right angles to each other, actuated by two cranks, the relative velocities, length of stroke, and angular positions of which all admit of adjustment, and consequently the mirror can be traversed over the polisher in an infinite variety of curves; a method of motion since adopted by Dr. Common and described later.

A very simple machine for grinding and polishing specula of small size was contrived by the Rev. William Hodgson, M.A., of Brathay, who has followed the general principles introduced by Lord Rosse, but has arranged the apparatus on the foundation of an ordinary turning lathe, driven by a foot-wheel, which, with an old form of overhead motion, and a part of the horizontal grinding machine shown in fig. 52, are the principal portions. This contrivance, therefore, possesses the recommendation of being composed in great measure of the ordinary apparatus possessed by most amateurs, and may be readily fitted up for an occasional purpose in those cases which would scarcely be considered of sufficient importance for the construction of more elaborate machines.

Fig. 270 represents a modification of the arrangement of Mr. Hodgson's machine; the cast-iron frame, *a*, carrying the vertical mandrel of the horizontal grinding machine, is fixed

behind the lathe-bearers, either by a bolt passing through the bearer; or a short supplementary bearer is fixed at the back, and the frame is held by a wedge beneath, as shown in fig. 52.

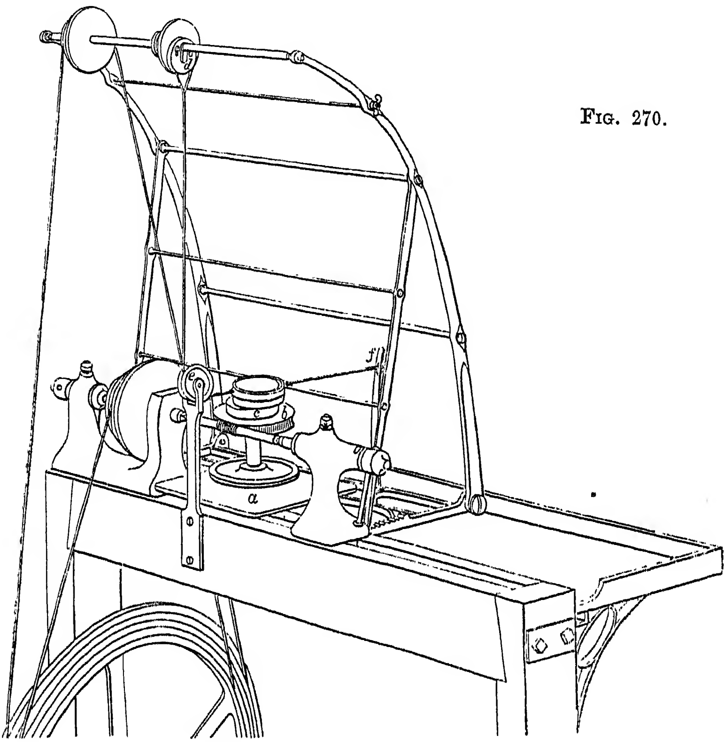


FIG. 270.

The speculum is mounted on a chuck, *b*, fixed on the screw of the vertical mandrel, in the usual manner, and the edge of the chuck is cut as a worm wheel, which is driven by a tangent screw mounted between the mandrel and popit-head of the lathe by which a slow rotatory motion is given to the speculum, *c*. The polisher, which is placed upon the speculum, is encircled by a loose ring, and a reciprocating motion is given to the ring, which allows of the very slow rotation of the polisher, exactly as in Lord Rosse's arrangement.

The reciprocating motion of the polisher across the face of the speculum is obtained after the method adopted by the late Professor Willis for giving a reciprocating motion to his vertical sawing machine, shown in fig. 729, Vol. II., the only

changes being those required in the alteration of the movement from the vertical to the horizontal position. For this purpose the spindle of the overhead motion is fitted with an adjustable eccentric, shown at *d*, a loop encircles the eccentric, and terminates in a catgut band that passes under the guide pulley *e*, and is connected to the front of the ring embracing the polisher. A second band proceeds from the back of the ring, and is connected to a vertical steel spring, *f*, fixed at the back of the lathe. Motion is communicated to the lathe mandrel by the band leading to the foot wheel in the ordinary manner, and a second band is led to the over-head motion, either from the foot wheel, as shown in the figure, or from the pulley of the mandrel. The relative velocities of the polisher and speculum may be readily adjusted by shifting the bands to different grooves on the driving pulleys, and the length of stroke of the polisher is adjusted by shifting the position of the eccentric, which, as seen in the figure, is fixed on the front of a plain pulley by two clamping screws. The height of the guide pulley *e*, and the spring *f*, are adjusted to the level of the polisher.

With this arrangement of apparatus, Mr. Hodgson succeeded without material difficulty in grinding and polishing specula, one of which was $3\frac{1}{2}$ inches aperture, with a focal length of 33 inches; this had a tolerably good figure and performed satisfactorily.

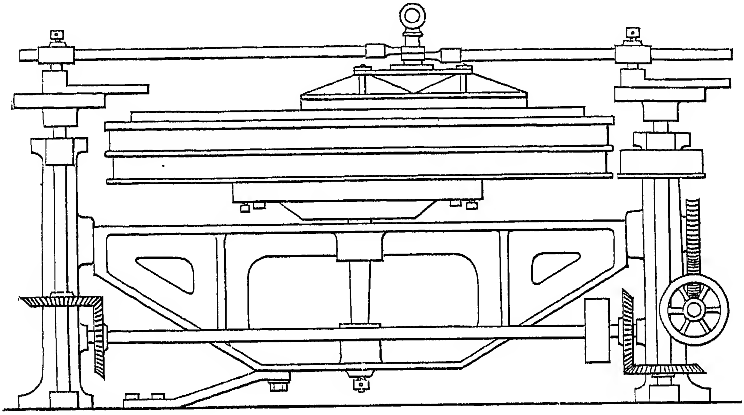
In figuring this speculum an elliptical polisher was used, the proportions of which were the same as those recommended by Mr. Edwards; and to allow of the free rotation of the polisher, which was made of a mixture of lead and tin, the upper part was finished as a cylinder, to fit loosely in the ring, and the length of traverse of the center of the polisher across that of the speculum, was rather more than one inch. Mr. Hodgson suggested that should it be considered desirable, a second guide pulley may be placed at the back, instead of the steel spring, and a second eccentric on the spindle of the over-head motion would answer quite as well to produce the back stroke; but the plan which he followed appeared in his own case to be more easily executed.

The earlier attempts to replace metal by silvered glass for the specula of reflecting telescopes were made in 1860, at the suggestion of Sir John Herschel, and since, it has been proved that silvered glass specula possess every capability for astronomical purposes; they transmit more than 90 per cent. of the light that falls upon them, their weight is but one-eighth that of metal specula of similar aperture, they are far less costly, and the material is more tractable with less risk in its grinding, on the other hand, the glass suitable to the purpose requires extraordinary care in the mixing, melting, casting and cooling to secure the necessary perfect equality throughout its substance. Sir Henry Bessemer's long-continued efforts to turn the curvatures of large reflecting glass mirrors with the diamond have apparently failed, but Professor Draper of New York, Dr. Common at Ealing, and others, have produced numerous satisfactory large glass specula by grinding. The excellent results obtained from an 18 inch and subsequently from a 36 inch silver upon glass specula in astronomical photography, and from those used in the Solar Eclipse Expedition of 1889, induced Dr. Common to undertake the production of another of 5 feet diameter, which, after long-continued labours upon a first and upon a second disc of glass, was successfully completed; the telescope and its mirror are described in a paper read before the Royal Astronomical Society in December, 1891, and the apparatus used for grinding and figuring the glass speculum is modified, but based upon those of the Earl of Rosse, Dr. Draper, and that used by Sir Howard Grubb in the construction of the 4 foot mirror of the Melbourne telescope.

The main parts of the machine are indicated in fig. 271; the frame has two long massive vertical sides, the ends of which are alone shown, parallel with one another and securely braced together at one end, the whole forming three sides of a square which is firmly fixed on a base of masonry. The glass disc in its cell is carried on a large faceplate which is attached by fixing and levelling screws to a smaller plate beneath, that is mounted on the upper end of a vertical spindle, which latter runs in conical collars and on an end screw in the center of a deep braced iron girder supported by trunnions in bearings fixed to the open ends of the frame; throughout the grinding

the spindle is retained exactly vertical by a bent bar attached to the base of the girder and bolted to the floor, and with the bolt released, the girder may be turned one quarter round by a screw worm and a toothed quadrant fixed to one of its trunnions to place the glass vertically, arranged by Dr. Common to permit the optical testing of the mirror during the process of figuring without its removal from the machine.

Fig. 271.



Two vertical spindles mounted on the sides at the closed end of the frame and driven by the main shaft by equal bevel wheels, carry adjustable eccentrics at their upper ends, from each of which a rod, variable as to its length, attaches by rings to the central post of the grinding tool, which latter rests on the glass and rotates by its surface contact. One of these spindles also carries a pulley, a band from which to the periphery of the large faceplate puts the glass disc in slow rotation. The arrangement is somewhat similar to that employed by Lord Blythswood, fig. 262, and in like manner, by the different reciprocatory movements of the rods and the rotation of the glass, every point in the face of the grinding tool travels in an epitroithoidal path susceptible of indefinite variations by the adjustments of the eccentrics and lengths of the rods, and, of being limited as to its action to any zone of the mirror from the circumference to the center.

The 5 foot mirror, 5 inches thick, was intended to have a focal length of 28 feet, 7 inches, which required a concave

spherical curvature six-tenths of an inch deep at the center. A pair of thick iron *tools*, 40 inches diameter, strengthened behind by ribs to ensure permanence of form, the entire superficies of the convex tool cast in 1 inch squares with deep grooves three-quarters of an inch wide for their intervals, a corner of one square falling on the center of the tool, and the concave tool left plain, were first turned to iron templates accurately prepared to this curvature; this pair of tools were then ground together in the manner already described under the test of a spherometer of the character of fig. 263, until their curvatures proved exactly correct, the concave tool thenceforth serving to obtain the curvatures of the various grinders used upon the glass.

The curve was first rough-ground with Nos. 12, 20 and 36 emery successively applied to the glass on a lead block 22 inches diameter and 4 inches thick, weighing 400 lbs., roughened on its convex face with a cold chisel and pierced with numerous three-quarter inch holes for the passage of the supplies of emery and water. The superficially squared iron tool, 40 inches diameter, just mentioned, followed for the smooth grinding, carried out with gradually reduced sizes of emery, the last being more than twice as fine as ordinary flour emery; the tool partially counterbalanced to about half its weight, when using this last, by weights attached to a line passing over pulleys overhead down to the ring of its central post; the tools plentifully supplied with water throughout, a little soap being dissolved in the water used with the finer emeries; and the mirror, tools and machine washed down between every change to remove all traces of the previous coarser powders. A close approach to the curvature and an excellent surface having been attained by the fine grinding, the superficies was further smoothed prior to the polishing with a glass tool 28 inches diameter by 2 inches thick, ground to its curvature in the iron tool and afterwards grooved into squares, attached to an iron back by screws, their heads countersunk below the convex surface of the glass. The tools for the polishing, which includes the figuring or corrections of the curvature, used with washed rouge and putty powder and water, ground to form in the iron tool and then grooved on their faces, had their squares covered with resin melted with

turpentine, which was preferred by the Earl of Rosse as more cleanly than the pitch generally used. Dr. Common considers the material of the polisher as of secondary importance, permanence of form being the essential, and this, as with the glass tool, was secured by attaching the discs to strong ribbed iron backs. Three polishers were used, one of slate half the diameter of the mirror for the first general polishing, the others being slate and lead, both about 16 inches diameter, for the figuring.

The film of metallic silver which reflects the objects, remarkable in its tenuity, tenacity, equality and lustre, is deposited on the concave surface of the mirror by a chemical process discovered by Brashear, and since varied as to the solutions employed by Steinheils, Foucault, and others. Professor Draper prefers M. Cimeg's method which employs tartrate of potash and soda (Rochelle salt), with which he never failed to secure a perfect film. Dr. Draper says: "The operation which in many respects resembles that of M. Foucault is divided into (1) cleaning the glass, (2) preparing the solutions, (3) warming the glass, (4) immersion and stay in the silver solution, and (5) polishing. It should be carried out in a room warmed to 70° Fahr. at least. The description is for a $15\frac{1}{2}$ inch mirror.—1st. Clean the glass by rubbing it thoroughly with nitric acid, then wash well with plenty of water and set on edge on filtering paper to dry. Then cover it with a mixture of alcohol and prepared chalk and allow evaporation to take place. Rub in succession with many pieces of cotton flannel, this leaves the surface almost chemically clean. 2ndly. Dissolve 560 grains of Rochelle salt in two or three ounces of water and filter. Dissolve 800 grains of nitrate of silver in four ounces of water. Take one ounce of strong ammonia of commerce and add the nitrate solution to it until a brown precipitate remains undissolved. Then add more ammonia and again nitrate of silver solution. This alternate addition to be carefully continued until the silver solution is exhausted, when some of the brown precipitate should remain in suspension. The mixture then contains an undissolved excess of oxide of silver. Just before using, mix with the Rochelle salt solution and add water enough to make 22 ounces. The vessel in which the silvering is to be performed

may be a circular dish of ordinary tin plate sixteen and a half inches in diameter, with a flat bottom and perpendicular sides one inch high, and coated inside with a mixture of equal parts of bees-wax and rosin. At opposite ends of one diameter two short narrow pieces of wood one-eighth thick are cemented, they are to keep the face of the mirror from the bottom of the vessel, and permit of a rocking motion being given to the glass. Before using, it is necessary to touch any cracks that may have formed in the wax with a hot iron;—the vessel, too, must always, especially if partly silvered, be cleaned with nitric acid and water and left filled with cold water till needed. 3rdly. In order to secure firm and hard deposits in the shortest time and with weak solutions, it is desirable, although not necessary, to warm the glass slightly. This is best done by putting it into a tub or other suitably sized vessel and pouring in water enough to cover the glass. Then hot water is gradually stirred in until the mixture reaches 100° Fahr. It is also advantageous to place the vessels containing the ingredients of the silvering solution in a similar bath for a short time. 4thly. On taking the glass out of the hot water, carry it to the silvering vessel, into which an assistant has just previously poured the mixed silvering solutions, and immediately immerse it face downwards, dipping in first one edge and then quickly letting down the other till the face is horizontal. The back of the glass is of course not covered with the fluid. Place the whole apparatus before a window, keep up a slow rocking motion of the glass and watch for the appearance of the bright silver film. The solution quickly turns brown and the silver soon after appears, usually in from 3 to 5 minutes. Leave the mirror in the liquid about six times as long. At the expiration of the 20 or 30 minutes, lift it out and look through it at some very bright object; if this object is scarcely visible, the silver surface must then be washed with plenty of water and the mirror set on edge on bibulous paper to dry. If on the contrary it is too thin, put it gently back, and leave it till thick enough. When polished the silver ought, if held between the eye and the sun, to show his disc of a light blue tint. On coming out of the bath the metallic surface should have a rosy golden colour by reflected light. 5thly. When the mirror is thoroughly dry and no drops of water remain about its edges,

lay it upon its back upon a thoroughly dusted table. Take a piece of the softest thin buckskin, and stuff it loosely with cotton to make a rubber. Avoid using the edge pieces of a skin, which are always hard and contain nodules of lime. Go gently over the whole silver surface in circular strokes to commence the removal of the rosy golden film and to condense the silver. Then, having put some very fine rouge on a piece of buckskin laid flat on the table, impregnate the rubber with it. The best stroke for polishing is a motion in small circles, at times going gradually round on the mirror, at times across on the various chords. At the end of an hour of continuous gentle rubbing with occasional touches on the flat rouged skin, the surface will be polished so as to be perfectly black in oblique positions, and, with even moderate care, scratchless." "The thickness of the silver thus deposited is about $\frac{1}{200000}$ of an inch, gold leaf when equally transparent is estimated at the same fraction. The actual value of the amount on a $15\frac{1}{2}$ inch mirror is not quite a cent, the weight being less than four grains, if the directions above given are followed. Variations in thickness in this film of silver on various parts of the face of the mirror are consequently only small fractions of $\frac{1}{200000}$ of an inch, and are therefore of no optical moment whatever; and if a glass has been properly silvered and shows the sun of the same colour and intensity through all parts of its surface, the most delicate optical tests fail to indicate any difference in figure between the silver and the glass underneath. The durability of these silver films varies, depending on the circumstances under which they are placed and the method of preparation. Sulphuretted hydrogen tarnishes them quickly. Drops of water may split the silver off. Under certain circumstances, too, minute fissures will spread all over the surface of the silver, and it will apparently lose its adhesion to the glass. This phenomenon seems to be connected with a continued exposure to dampness, and is avoided by grinding the edge of the mirror flat, and keeping it covered when not in use with a sheet of flat plate glass. Heat seems to have no prejudicial effect, although it might have been supposed that the difference in expansibility would have overcome the mutual adhesion. Generally, silvered mirrors are very enduring, and will bear polishing repeatedly if properly dried by

heat." "In order to guard against tarnishing, experiments were at first made in gilding silver films, but were abandoned when found to be unnecessary. A partial conversion of the silver film into a golden one, when it will resist sulphuretted hydrogen, can be accomplished as follows:—Take 3 grains of hyposulphate of soda, and dissolve it in one ounce of water. Add to it slowly a solution in water of 1 grain of chloride of gold; a lemon yellow liquid results, which eventually becomes clear. Immerse the silvered glass in it for twenty-four hours, an exchange takes place and the film becomes yellowish. Glass prepared in this way remains unhurt among other pieces of plain silvered glass which change, some to yellow and some to blue from exposure to coal gas."

In silvering the 5 foot mirror Dr. Common employed loaf sugar as the reducing agent. Separate 10 per cent. solutions of nitrate of silver and of caustic potash were mixed together and ammonia added until the precipitate was redissolved, after which the mixture was diluted to a pale brown colour. A 10 per cent. solution of the sugar with an equal quantity of pure alcohol and ½ per cent. of nitric acid in distilled water were then added immediately before use. Suspending the mirror face downwards, preferred to prevent the settlement of dust or possible particles in the solutions which may produce pin holes in the film, could not be risked with the 5 foot mirror from its weight, upwards of half a ton. A rim of thick paper saturated with paraffine was cemented around its margin to form a deep dish and, after the mirror had been cleaned, the carefully filtered solutions were mixed and poured on its face. A uniform film was deposited in about 2 hours, which, when washed and dried, was consolidated and polished with soft leather rubbers as lately described. The mirror when in the telescope and not in use is excluded from the air by a sheet of plate glass which rests on its cell; the film remains in condition for about twelve months and it may always be readily cleaned off and the glass resilvered. The tenuity of the film, previously referred to, may perhaps be better appreciated in the circumstance that, in removing an experimental film to allow the mirror to be further figured, Dr. Common carefully collected the whole of its silver which was found to weigh but little more than that contained in a threepenny piece.

Although more easily worked and less brittle than speculum metal, glass has inherent peculiarities which require extraordinary care and patience in working it to the accuracy required for the optical purposes under consideration, and these difficulties are enormously increased with work of so large a scale. The 5 foot glass mirror is probably one of the finest examples of accurate form produced by pure abrasion extant, but it was not produced without almost incredible labour and, as the result of experience in the methods and appliances gained by many years' continuous work upon several others, one of which was of the same dimensions. The rough grinding occupied about a month, and the smoothing with the iron tool and the first polishing with the slate and glass tools about as long; the glass tool with a plain spherical superficies was found to act admirably with the coarser emeries, but not so with the finer, and from its intimate contact with the mirror when using the finest it was found to *seize* or adhere and to scratch or *tear* the surface by its edge, an effect which entirely disappeared so soon as the convex face of the glass tool was grooved into squares.*

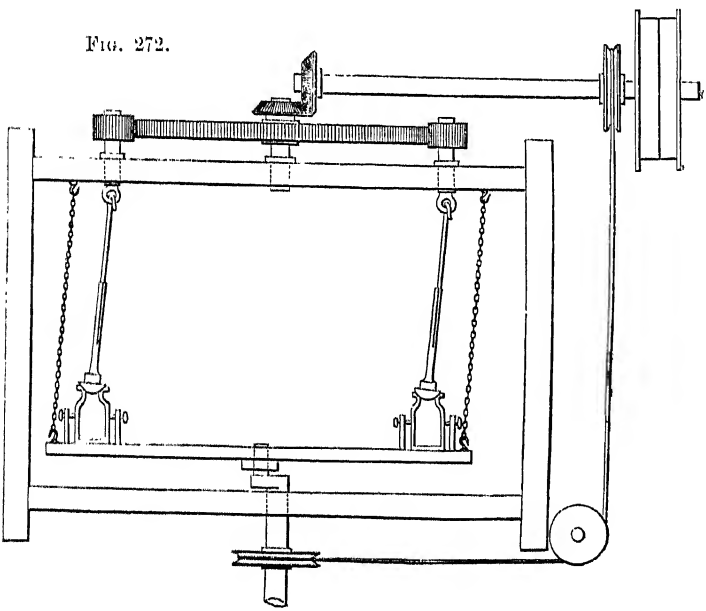
The expansion of the glass from the heat evolved also required the work to be continually intermitted, to avoid the risk of the mirror on cooling taking a different curvature to that ground or polished when it had heated; thus in the polishing but two separate hours' work at a considerable interval could be safely performed on the same day, and for the same reason the figuring with the resin covered tool could only be carried on for still less periods. During the fine grinding the adjustments given to the rods and eccentrics were varied every ten minutes, and the path of the tool was thus slightly altered every five minutes throughout the figuring. All the powders, first washed by elutriation, were used with plentiful supplies of water, extreme precautions were employed to remove every

* Dr. Draper found precisely the same difficulty in using the iron tool with the finest emery, and thereupon, in default of other appliances, grooved the face of the tool in the following ingenious manner. The convex face was marked out into squares and intervals, and every square covered by a corresponding piece of sheet wax moistened with Canada balsam, and the convex was next pressed in the concave tool to thoroughly attach them. A rim of wax was then raised around the periphery of the tool and the grooves or uncovered parts corroded away to a sufficient depth by flooding the face with nitric acid.

trace of each before using the next and, with the finer, to guard the powders and mirror from the access of dust which, if present, produces scratches that can only be removed by going back and repeating some previous stage of the grinding. The mirror was invariably protected from currents of air and the grinding room maintained at one temperature, a decided advantage in the latter respect also accruing from the apparently small matter of keeping the finer powders for some days in the grinding room to acquire the same temperature; and the polishing was always found to be better on damp days from the comparative absence of atmospheric dust. Beyond all this, it should be added, the 5 foot mirror was four times reground and patiently repolished and figured before it was considered to have attained the maximum of possible accuracy.

A machine employed at some pottery works, for grinding the spherical stoppers of air-tight earthenware jars, is represented

FIG. 272.



in the diagram, fig. 272. The stoppers and jars are ground together in the state in which they leave the kiln, without

separate preparation. About a dozen jars are fixed by clamping apparatus around the margin of a circular table, that is suspended by swing chains from the upper part of the frame of the machine. The circular table is swung bodily in a circle of about three inches diameter, by a slowly revolving eccentric placed beneath, and every stopper is made to revolve with considerable rapidity within the spherical fitting of the jar by the following arrangement.

A large toothed wheel fixed horizontally in the center of the upper part of the frame, communicates by a pair of bevel wheels with a horizontal shaft driven by a strap from the engine. Around the central wheel about a dozen small pinions are mounted in separate bearings at equal distances, so as to be all driven at the same time by the central wheel. The axis of every pinion passes through its bearing, and terminates beneath in an eye to which a hooked rod is suspended. To allow of variation in the length, this rod is fitted within a piece of gas-tube with a slit down the side for a pin to ensure the rotation of the tube, which terminates at its lower extremity in a chuck for the attachment of the stopper. The rapid revolution of the stoppers gives the grinding motion, and the slow circular swinging of the table derived from the eccentric beneath, gives the continual change of position required for the true spherical form. The weight of the tube and chuck supplies the pressure for the grinding, which is begun with sand and water, and completed with emery, the time occupied in grinding a dozen jars being about one hour. This machine is perfectly successful in producing the true spherical fitting, but is now little used, as it is found more economical to grind the stoppers and jars together in the lathe by hand, the true spherical form not being considered by manufacturers of sufficient importance to justify the additional expense of the apparatus.

CHAPTER IX.

GLASS CUTTING.

SECT. I.—GRINDING, SMOOTHING, AND POLISHING CUT-GLASS BY HAND.

THE larger proportion of glass cutting, or the grinding and polishing of cut glass for household and other purposes, is usually effected by hand on revolving wheels of iron, stone, or wood, mounted on horizontal spindles after the same general method as the grindstones and buff-wheels of the cutler; but glass grinding requires a plentiful supply of sand and water for the iron wheels, water alone for the stone wheels, and water and various polishing powders for the wood wheels, which usually runs in a small stream from either a hopper-shaped box, or a can, placed above the revolving wheel; this feed is led by a sloping channel to the upper edge of the wheel, and a small piece of wood is placed nearly upright and almost in contact with the latter, a little in advance of the point at which the feed is delivered, in order to distribute it equally over the edge. A splash-board is fixed behind the wheel, to catch the water thrown off by centrifugal force and lead it to the trough placed beneath; a second splash-board is sometimes fixed in front, to protect the operator from the wet.

Figs. 273 and 274 represent, in two views, the general arrangement of the apparatus employed in large manufactories where the spindles are usually driven by steam power, but in small workshops and for occasional purposes, the foot-wheel and treadle are employed in much the same manner as in the small grinding machine shown in fig. 5, except that the spindles are placed a few inches higher. The wheels, whether of iron, stone, or wood, are generally made from about 6 to 20 inches diameter, and about 1 to $1\frac{1}{2}$ in thickness; a considerable variety is required of all the three kinds, with flat, angular, rounded, or concave edges, to suit the different forms in which the glass is to be cut; the wheels are mounted upon

separate spindles, and are exchanged in exactly the same manner as those used by cutlers.

The majority of hollow works in cut glass, such as wine glasses, jugs and decanters, is blown to the circular form, and the ornament is entirely produced by external grinding and

Fig. 273.

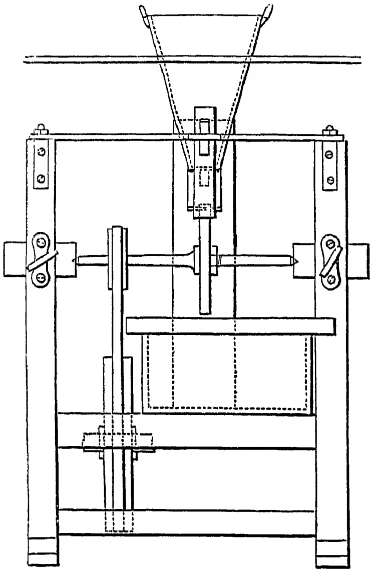
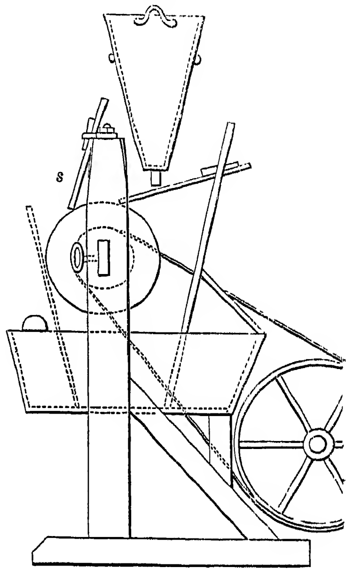


Fig. 274.



polishing; some few are blown in figured moulds, and the external ornament thus produced is finished by cutting, but this last method is never used for the best works because, in the process of blowing, the interior surface of the glass somewhat follows the facets or corrugations the exterior receives from the mould, and is therefore more or less undulating instead of plane, to the detriment of the lustre and effect of the subsequent cutting. Small solid objects, such as the prisms and drops for chandeliers, are mostly *pinched*, or the glass, while red hot, is pressed into the cavities of metal moulds something like those for casting bullets, but formed with the required facets; and for chandelier drops the moulds are provided with steel pins, that pierce the apertures for the brass wires by which the glass drops are united to form the ornament.

The first process in glass-cutting, *roughing*, or the rough grinding, is performed with cast-iron wheels, called *mills*, turned truly circular and of the required figure whilst on their own spindles; the mills are supplied with fine sand, that has been previously washed and sifted to free it from dirt or coarse particles of grit. The sand is placed in the hopper, which is filled up with water, and the opening at the bottom adjusted by a plug, so as to allow a stream of the mixed sand and water, of about one quarter of an inch diameter, to flow through. The glass to be ground is applied either above or below the center of the mill, according to the convenience of the operator. If the object be large and much has to be ground away the work is generally applied above the center of the wheels, as this position is less fatiguing for the arms; hollow objects are generally sufficiently transparent to allow of the operator looking *through* them to see the progress of the work, but if of such a form that this cannot be observed by looking through the glass, the operator then depends entirely upon his judgment and practice, and his work is then known as *blind cutting*. Small solid objects, and such as are not transparent, are mostly applied below the center to enable the workman to watch the progress of the cutting; in this case a wooden bar is laid across the water trough, upon which the arms are rested, partly to avoid fatigue and partly to give greater steadiness.

When the object to be ground is large, and is required to have several faces, or *flutes*, the circumference is divided with a pair of compasses into the required number of parts for the principal circle, and the divisions are roughly scratched with an old triangular file, ground like a triangular turning tool; the height of the flutes is also marked on the best works. These divisions assist the workmen in cutting the first circle of flutes to uniform size, and this then serves as the basis for all the other circles of flutes, generally placed intermediately to those of an adjacent circle, and successively produced under the guidance of the eye alone. Small articles, such as wine-glasses, are not usually divided with the compasses, unless for the best works, as, from constant habit, the glass-cutters attain considerable dexterity in grinding any regular number of faces upon a circular object.

As a rule the edge of the mill is alone employed for cutting,

and the faces produced, therefore, copy its curvature, and are ground concave instead of flat, which also has the advantage of making the intersections of the edges appear sharper; when, however, the surfaces are required to be quite flat, the side of the mill is employed in the same manner as for lapping the metals. For cutting long straight faces, the work is held parallel with the axis of the mill, and gradually traversed from end to end, over one with a flat edge. For curved surfaces, such as the neck of a claret jug, a mill with a slightly rounded edge is used, and the work is traversed in a curved path. For angular grooves, or *splits*, up the side of a decanter or similar object, an angular edged mill is employed, and the decanter is held upright, or at right angles to its axis, the same position is also employed for convex ribs, called *pillars*, for which a a concave mill is used. In rough grinding, the work is applied with considerable pressure, and large deeply cut flutes sometimes require as much as one-horse power to drive a single mill. When the supply of water in the hopper is exhausted it is ladled back from the trough, the same supply of water serving for several days' use, or until it becomes dirty.

The second process, that of smooth-grinding the flutes, is done upon fine York or Warrington gritstones, on Craig Leith stones, a variety of the Yorkshire grit which contains numerous minute metallic particles of a brilliant gold-like colour, and on Blue Mitre stones, a kind of slate. These varieties of gritstones are chosen as being the finest and most compact in grain, and as capable of retaining the sharp angular edges to which they have been prepared, a quality in which the last-named stone is pre-eminent. The Yorkshire stones are, perhaps, the hardest, and are usually selected from the finest grained pieces of paving slabs; the blue mitre stones frequently contain holes running up to about one quarter of an inch diameter, very similar to worm holes in wood, which are filled with a very hard stonelike substance, and such faults when they occur in the periphery render the stone quite useless for grinding glass.

The stones are ground flat and parallel on their sides, principally that they may be in perfect balance when running, and, as already said, these flat sides are also sometimes used for grinding. The sides are ground true with an iron bar laid

across them, as near their diameter as the spindle will allow, fed with sand and water; and their edges after being turned perfectly circular are then shaped square, round or angular as required, effected after the same manner with the end of an iron bar supported on the water trough and supplied with sand and water. The stones are afterwards smoothed, first, with a piece of stone of the same quality rubbed against them held in the hand, and then with a flint boulder similarly applied, the stones in revolution; this leaves the stone quite smooth and almost polished. A flint boulder also usually lies on the frame of the machine, and is employed from time to time to repair the edge of the wheel when that is in use. If the stones were left with a rough surface, the glass would not hang to them, but would slip away and be quite unmanageable. A smaller stream of water is required than with the cast-iron mill, and a straw frequently serves as the channel for leading the water from the can to the stone. A piece of sponge is often attached to the sloping board *s*, in front of the straw, to moisten the stone uniformly, as that must be kept tolerably wet or it will generate so much heat as to break the glass.

More care is required in the smoothing than in the roughing, as this second grinding gives the finished form to the glass, and at the same time a very smooth surface. If the smoothing is carried on too vigorously the stone is liable to *jar* the glass or put it in vibration, this causes the latter to *squeak*, or make a noise like a dry cart wheel, and frequently the glass breaks immediately afterwards, unless it be applied to the stone with reduced pressure and also more firmly held in order to prevent it from vibrating. In smoothing the slender neck of a bottle, a cork is sometimes inserted to check the vibration, which never occurs in the rough grinding with loose sand, and is less frequent in smoothing with Warrington stones than with the harder York stones. The work is applied to the stone for smoothing in exactly the same manner as upon the mill for roughing, but it is more frequently held below the center of the stone, and in finishing straight flutes these are often applied upright, or at right angles to the axis of the stone, as in this position they may be made somewhat straighter and smoothed rather more expeditiously. The stones

used for this purpose are sometimes as much as three inches in thickness.

After the smooth grinding the glass is polished on wheels of willow, cut transversely out of round timber and turned true and smooth, or, frequently, although less generally, upon the edges of wheels built up of cork in the manner described in the catalogue, WHEELS, article 51, which are considered by some to give a more lustrous polish. The wood or cork wheels are charged with pumice stone powder, mixed with water applied with a brush; sometimes rotten stone is mixed with the pumice stone. As in cutting, the edges of the wheels are principally used, but the work is almost always applied on the top of the wheel, and instead of the glass being held in one position and traversed endways, it is twisted about in all directions to remove the marks made by the stone in smoothing. The final lustre is given with wet putty powder applied also on willow and on the cork wheels. Wheel brushes of about 8 or 10 inches diameter, supplied with pumice stone, rotten-stone, or putty powder, are also used as an expeditious means of polishing those parts of cut glass in which the sharpness of the angles is not considered to be of great importance, but the use of the wheel brushes is avoided as much as possible in polishing the best works.

In fitting the conical stoppers into glass bottles, the hollow cone in the bottle is ground by means of a solid cone of iron, sometimes roughened like a steel for sharpening knives. The cone is chucked on a lathe mandrel, and fed with emery and water. The stoppers are fixed in a hollow wood chuck by slight blows of a mallet, and are ground also with emery and water applied on a grinder made of a piece of sheet iron, hammered around a cone of the same angle and left with two flaps or ears by which the grinder is held and compressed upon the revolving glass stopper. The cones are ground separately until the stopper will enter the bottle to within about one-sixteenth of an inch of the intended position, the two are then slightly ground together for the exact fitting. The stoppers of the best works are afterwards polished on the edge of the willow wheels, in the same manner as cut glass. The internal cone is polished on a small willow cone revolving in the lathe. The large stoppers for medical bottles are sometimes rough

ground with sand on the flat side of a mill made of stout sheet iron, which is also employed for grinding the bottom of the bottle flat.

Glass drops for chandeliers are cut upon the flat faces of wheels, which sometimes revolve horizontally, and are almost entirely concealed within wooden cases to catch the dirt, only a small opening being left for applying the drops. They are roughed with sand and water on iron mills, smoothed on stones, and polished on lead laps supplied with rotten-stone and water; the lead is considered to produce a black polish that reflects the prismatic colours in a higher degree than when wood is employed as the material for the polisher.

Glass cutting in bevelling the surface edges of large and small panels of plate glass for insertion in furniture, may be considered as almost a distinct branch of the art, the majority of the work is carried out by manual dexterity alone, and machines are used only for pieces too large for safe or convenient manipulation; in either case the appliances are generally of the most simple character.

Straight rectilinear bevels are ground and polished on a series of wheels which revolve horizontally on the tops of vertical spindles, which latter are placed in lines along the workshop about 6 or 8 feet apart, and the surface of every wheel stands just above a wooden casing, surrounding its supports, which catches the major part of the grinding powders and water thrown off. The piece of polished plate glass is cut to the required size with a diamond and the fractured edges are usually left untouched, as when the panels are mounted they are concealed within the rebate in which they are held. The bevel is ground along the surface edge of every side of the glass seriatim, upon the surface of a thick flat iron wheel about 3 feet 6 inches diameter, without any superstructure but otherwise a small copy of the stone polisher's sanding plate, fig. 185, fed by a continuous stream of sand and water about the size of a quill, which falls upon the flat surface of the wheel an inch or two within its periphery, regulated by a tap in a tube from a funnel-shaped receptacle above. Small pieces of glass are held in one or both hands

according to their size and, as with all, they are slowly passed straight across the surface of the revolving iron plate at a tangent to a circle about four inches from its circumference. The operator looks through the glass to watch the progress of the cutting, and accelerates or delays the traverse as he judges necessary, throughout which, the fractured edge of the glass serves him as some guide both as to the width and parallelism of the bevel ground; but the extent ground away and the equality in the inclination of the bevel, result entirely from practice and his steadiness of hand in holding the glass. Larger pieces are held horizontally in the direction of their traverse and sloping downwards in the other towards the wheel, the uppermost long edge pressed against the front of the body just below the waist by both arms stretched out across them, the fingers doubled under the opposite edge to either side of the portion that rests on the surface of the wheel; the hands are shifted along the work as the grinding progresses and the body is slightly swayed to traverse the work. For the ends of long pieces one side edge is pressed against the hip with one arm across the body and the other across the glass, the hands opposite one another. These methods of holding large pieces greatly aid in maintaining equality in the inclination of the bevel, and panels up to 6 feet by 2 feet are commonly so ground by a single individual; for still larger work held and guided by the beveller in the same manner, he has one or two assistants whose duty is confined to supporting the weight of the glass at its ends.

After grinding, the bevels are smoothed upon the flat sides of Warrington gritstones, mounted in the same manner and of the same dimensions as the iron grinding wheels, which are kept constantly moist with a stream of water, and the glass is held and traversed across the surface a few inches from the edge just as in the grinding; the portion of the stone used wears away to a curve and the entire surface has to be renewed flat from time to time by turning. The polishing is effected first upon wood wheels with powdered pumice stone and water, and then to its final lustre upon others plentifully fed with rouge and water, the materials previously referred to for polishing plate glass. These are annular wheels of the same external diameter as those employed for the grinding, with

from 4 to 6 inches width of annular surface edge, the part used; they are built up of the wood the end way of the grain, and revolve horizontally.

Plain convex curvatures for the arched top of a panel, are ground and polished on the flat faces of the horizontal wheels previously used for grinding the rectilinear edges, the curve to which the glass has been cut being the only guide in twisting the work round to grind an equal width of bevel; a like curve that meets and forms internal angles with rectilinear portions of the work is generally so ground for the greater part of its length, after which it is completed into the corners, together with the straight bevels which form the other halves of these corners, by being ground and polished upon the wheels used for concave curves. Returned curves which run without break from convex to concave, such as the ogee, usually have the whole bevel wrought upon these last-named wheels.

The wheels used for concave and other curved edges are of iron, stone or wood as before, from 2 to 2 feet 6 inches diameter and from one to two inches thick, with square edges; they run vertically upon horizontal spindles and are used only upon their edges. The work is presented to the top of the wheel but grasped more firmly, because the narrow revolving edge upon which it rests affords but little reliable support; the workman stands at first rather to one side of the wheel to present the work at a horizontal angle to the line of its revolution, as the grinding progresses along the curve he gradually passes round in front of the wheel until he arrives at the other side at its completion, and this he repeats until the bevel is ground to the required breadth and equality. Under this management the grinding action is effected only by a narrow line on the edge of the stone at about 45° to its sides and to the width of the bevel on the glass, and this grinding, as it continually shifts around the curve, is never parallel with any radii of the latter, and the bevel is, therefore, flat throughout; it is also essential, for should the curve be held so that any of its radii become parallel with, or in the plane of the grinding action, the bevel at those parts necessarily copies the curvature of the periphery of the wheel and its surface is hollow instead of flat. Concave quadrants of small radius struck from the corners of square panels are ground

and polished to true bevels in this manner by dexterous management and the use of narrower square-edged wheels. Internal angles and square corners are also bevelled and polished on similar vertical square-edged wheels, with the rectilinear portion under operation held towards the top of the wheel, but out of parallelism with its axis.

A machine used for bevelling the straight edges of sheets of plate glass too large for working by hand, at Mr. A. Gibson's works at Dalston, consists of a long rigid frame placed to one side of the horizontal grinding wheel which stands at about the middle of its length. The level upper girders of the frame carry a tramway with a large table on wheels, the true upper surface of the table inclined towards the wheel at the appropriate angle to give the bevel to be ground. The glass lies on the table and projects a few inches beyond its lower edge to touch the grinding wheel across which it is traversed. Narrow long pieces are placed in contact with adjustable stops on the table that abut against the opposite edge to that being ground, and are also held down by several screw clamps with pieces of wood interposed, but the weight of wider pieces usually suffices to retain them in position without such fastenings. A chain from one end of the table is led around a pulley at a distance to a wheel and counterpoise overhead, about equal to the weight of the glass and table, that the traverse of the latter may be controlled by the hand of the operator as he watches the progress of the cutting. The grinding completed upon all four sides of several sheets of glass, the iron wheel is removed and those for smoothing and polishing substituted, the glass and all parts of the apparatus thoroughly washed with water on each exchange to remove all traces of the grinding powders just previously used.

Circular and elliptical discs, often of large size, are generally bevelled by hand upon the same horizontal revolving wheels, the margins of the glass, as before, serving the workman as a guide for the equal width of the bevel ground as he twists the pieces round, held in one or both hands, upon the surface of the wheels. For extensive and low-priced production, and largely on the Continent, these discs are ground and polished in machines. Circular pieces are cemented to the surfaces of round plates or chucks which are screwed one after another on

the top of a slowly revolving vertical mandrel, which has its axis in the same plane as the center of the thickness of the grinding wheel, put in rapid revolution on a horizontal axis above; the mandrel is also, and perhaps more frequently, mounted to revolve at a vertical inclination pointing away from the wheel. The grinding and polishing are effected by flat-edged wheels of comparatively large diameter, which are fed with sand and water and the polishing powders on the upper part of their edges; the bearings for their spindles are mounted upon a slide by which the wheels are advanced, so far as necessary, towards the surface edge of the glass which they cut by the lower portions of their peripheries. For ellipses the mandrel carries an oval chuck of the character of fig. 424, Vol. V., but with a screw nose, upon which removable flat oval chuck plates are placed with the work cemented upon them.

In a machine used at Stuttgart and patented by Mr. R. Friedel, 1889, the mandrel which carries the oval chuck is inclined from the wheel and is raised or lowered below the latter according to the dimensions of the work, by a vertical slide mounted on the front of the frame of the machine. The pieces of glass are fixed to the chuck plates by an easily detachable cement as before, and are also guarded from accidental displacement by a long steel spring bent at about the middle of its length into two parallel arms, like a pair of sugar tongs; this stands in a line with the wheel on the opposite side of the work, one end is secured to the head which carries the oval chuck and the other has a pad jointed to it which is made to press on the revolving piece of glass by a screw that compresses the upper arm of the spring on the lower. A second vertical slide at the back of the machine raises or depresses a frame which carries a horizontal spindle with the driving pulleys, and one end of a forked swing arm which has the grinding wheel at the other; the wheel, fed from above, cuts the glass by the lower portion of its edge and its descent is determined by an adjustable lever stop, worked by a screw, in contact with the under side of the wheel end of the swing arm; the general arrangements of these parts being very similar to those of the saw grinding machine, fig. 100. The wheels employed in all of these glass bevelling machines revolve so that they cut down the slope in grinding and

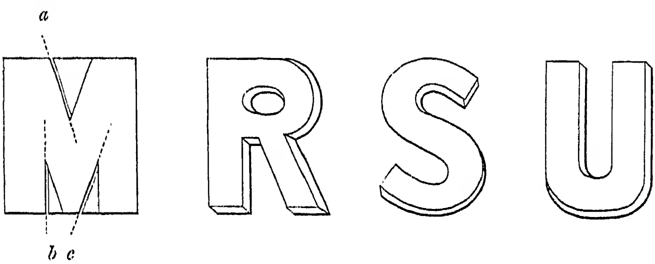
polishing, and they are of large diameter, to reduce so far as possible the curvature in the direction of its width to which they grind the bevel, but this curvature, however slight, sensibly interferes with the optical effect of the bevel, and the results are justly classed as inferior to those produced by hand.

The manufacture of the solid glass letters used for advertizing notices has many points of interest, the apparatus employed is of the most primitive character, but the results obtained leave little to be desired in form or finish. The alphabets are usually of the san-serriff or block letter character, figs. 275—278, and range in size from one to twelve inches in height, the largest of which do not exceed about one-eighth of an inch in thickness, their manufacture as carried out by Mr. Edmett is as follows.—The sheet glass is cut into rectangular pieces with a diamond to the sizes of a series of templates which will precisely contain each different letter of one alphabet; a large number of pieces for each letter being cut out at one time. These pieces are then marked on their surfaces to a second series of templates cut to the exact forms of the letters, held down upon them under the points of the outstretched fingers of the left hand, with a piece of greasy French chalk run around all the external and internal edges of the templates; the letters A, M, V and W, fig. 275, are also at the same time completed as to their external lateral forms by running a diamond along these edges of the templates and breaking off the superfluous glass between the fingers, but these and all the other letters require cutting on the wheel and with the diamond to complete their curvatures, inner straight lines and entering angles.

The cutting and polishing wheels used do not materially differ from those referred to with respect to fig. 274. They run vertically with their spindles mounted centrally across the sides of frames in the shape of strong wooden boxes open at the top and about 4 feet square by 3 feet high, required to catch the continuous supply of sand and water thrown off from the wheel, which falls from a receptacle above regulated by a tap on to the surface of a shoot, a triangular piece of sheet

iron turned up along its side edges like a tray, from the pointed end of which it flows on to the top of the wheel. The sand shoot is about 2 feet long, it slopes towards the wheel and rests towards its wide back end on a transverse bar and is supported near its point by a loop of wire and a cord to the ceiling by which it may be readily adjusted to deliver the grinding materials on the tops of wheels of different diameters; but for the economical production of large quantities of the same work the spindles and wheels are seldom changed, and

FIGS. 275. 276. 277. 278.



there are several lines of machines with wheels of different shapes and diameters arranged along the workshop to do portions of the work, which is transferred from one to another as its progresses.

The glass is first cut to the outlines of the letters, and taking one of the simplest already referred to as an example, fig. 275, the operator makes straight cuts along the chalk marked lines *a*, *b* and *c*, from the top and bottom edges so far as the internal angles, which he makes by grinding upon a flat edged iron wheel, from 18 inches diameter downwards by one-eighth of an inch and less thick. He holds the glass firmly in both hands, grasping the edge between the thumb and fingers wrapped round it close to the cut to check its vibration, and presents it at a vertical angle of about 45°, resting its edge on the top of the wheel near to the falling sand and water; and so soon as the periphery of the wheel has cut its way through, he gently advances the glass from him until he has completed a perfectly straight cut up into the internal angle. The three cuts made, the piece of glass is laid on a table and a diamond drawn along the opposing chalk marks and the refuse triangular shaped pieces are broken out

between the fingers, leaving the perfectly formed letter. The inner horizontal lines of such letters as E and Z are cut on the grinding wheel and their vertical and diagonal lines with the diamond; in like manner the one inner vertical line and the two inclined marginal lines of the tail of fig. 276 are cut on the wheel, and the diamond is then drawn along the short horizontal line between two of them and around the template into the end of the other for the bow of the R, and the pieces broken off.

The apertures in the bows of all the smaller-sized letters, fig. 276, are ground out as short ellipses upon bulbous or round-edged iron grinding wheels of small diameter and of a thickness greater than the width of the ellipse; the glass is first ground through from the under surface held in its sloping position but without movement upon the wheel, after which it is turned over and the aperture enlarged to the chalk mark and bevelled from the surface by pressing it about lengthwise and laterally on the edge of the wheel.

In the larger-sized letters the apertures in the bows are ground to the true D shape, first by grinding a rounded aperture and then lengthening one end of this and grinding the angles and the straight side upon a flat-edged wheel. For the internal margins of fig. 278, a rounded aperture is first ground through for the curve at the bottom, followed by one straight ground cut and the diamond for its fellow. The letter S, sometimes produced in the same manner, is shaped when of large size by two straight cuts made centrally up its hooks just into the internal terminal curves, followed by the reapplication of the template and the diamond run from the terminations of these cuts all around the margins of the letter. The apertures for the letter O are ground out from both surfaces of the glass upon the bulbous shaped iron wheels, but for all the larger, more expeditiously, by first grinding a slit the length of the intended aperture through the glass with the thin grinding wheel, and then running a diamond around a template a trifle less in size than that used for chalk-marking the ellipse, its cuts terminating just within the ends of the slit, the pieces are then broken out by tapping the under side of the glass with a round-faced hammer close to the diamond cuts and the aperture is completed to regular form on the round edged wheels;

the same system for avoiding risk and labour in grinding is also adopted for the apertures in other large letters.

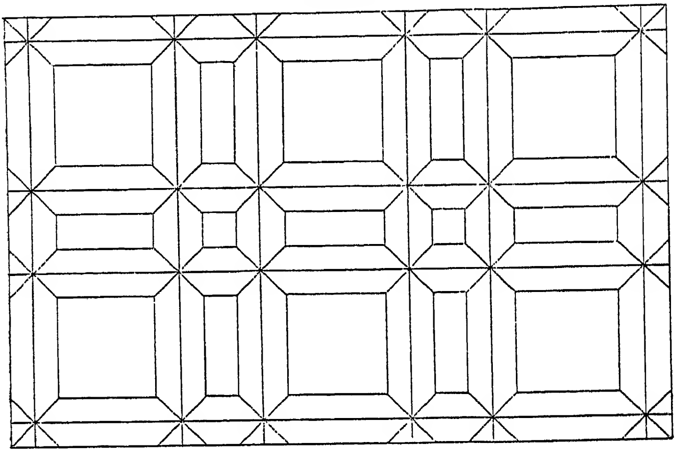
The fractures of the diamond cut edges are smoothed by passing them along the grinding wheel, after which, all the right hand and the lower horizontal marginal lines of the letters are bevelled on the surface face upon similar iron wheels and upon others turned to a single bevel, the peripheries of which latter form a sharp edge with one of their sides and are used to continue the bevels into internal angles. The bevels are then smooth ground upon similar gritstone wheels fed with water, and polished upon willow-wood wheels with the ordinary polishing powders and water. The letters are cut in clear glass or in opaque white faced glass; the under surfaces of the former are sized and covered with gold leaf, those of the latter only under the width that becomes transparent by the removal of the opaque skin in cutting the bevels, and finally, the under faces are painted with a thick coat of red lead oil varnish to preserve the gold leaf and to give a key for the cement by which the letters are attached in their positions.

SECT. II.—GLASS CUTTING BY MACHINERY.

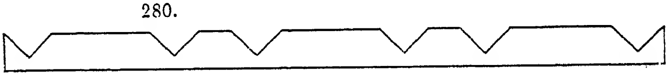
A large proportion of glass ware in daily use, decanters, glasses, dishes, scent and other bottles and other objects for service or ornament, is partly or entirely cut in facets over its surfaces. This often very elaborate ornamentation is executed by first marking all the main lines of its intersections, by just touching their extremities on the angular edge of the roughing wheel, and then cutting angular grooves across the work to these marks, and subsequently cutting all the other grooves to produce the facets between and parallel with or across the first upon the simple roughing, smoothing and polishing wheels used in fig. 274, the work held and entirely guided by hand, its truth depending throughout on the skill of the operator alone. It is remarkable that mechanical assistance has been so long delayed for this high class work, but it has been recently supplied, among others by a series of machines contrived by Mr. Charles Marlow, whose patented apparatus is worked by Messrs. Arculus of Birmingham.

For purposes of explanation figs. 279—284 represent some examples of this facetting upon oblong flat faces. The first fig. 279, known as *double square* cutting, is produced by pairs

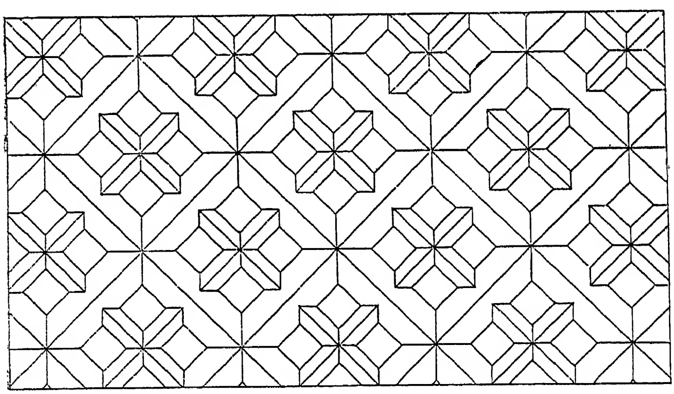
FIGS. 279.



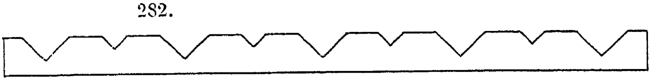
280.



281.



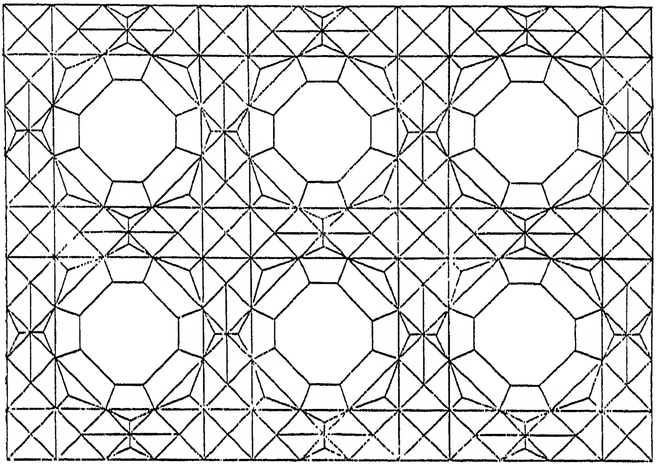
282.



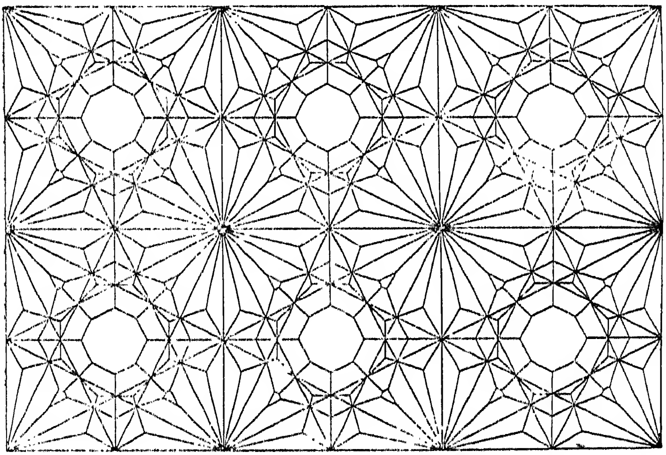
of straight angular grooves in juxtaposition, placed equidistantly both vertically and horizontally to leave equal square and oblong portions of the original surface untouched; the

positions of one such series of grooves being shown by the section, fig. 280. The second variety, fig. 281, or *laced diamond* cutting, has similar but single equidistant

FIGS. 283.



284.



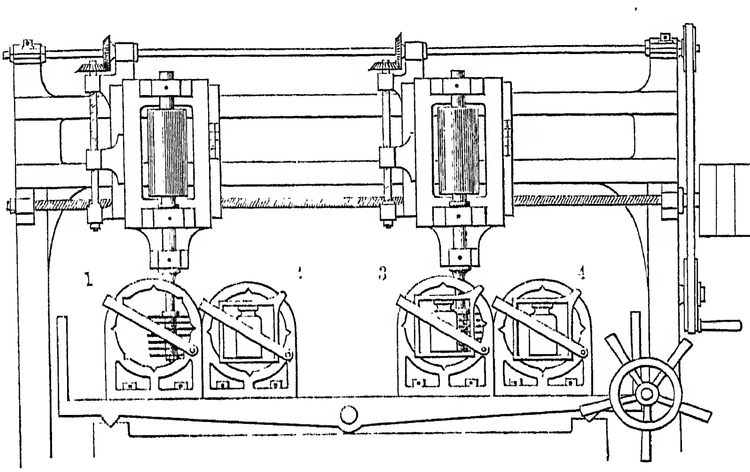
grooves at right angles, placed diagonally to the margins of the work, and the squares left standing between them are crossed by similar but shallower grooves cut centrally upon them and parallel with the main deeper grooves, shown also

by the diagonal section, fig. 282. *Hobnail cutting,* fig. 283, leaves octagonal spaces of the original surface, produced by pairs of equidistant vertical and horizontal grooves, their intersections crossed by single grooves of the same width and depth as those of the pairs placed diagonally to them. *Cobweb cutting,* fig. 284, has for its foundation single equidistant angular grooves crossing at right angles, to leave large squares of the original surface, of which there are six in the figure. These squares are then cut across from margin to margin of the work by other single grooves, all of the same depth and angle as those of the primary series, which run from every intersection or corner of each original square to the opposite further corners of every square adjacent to it; leaving octagons, differently shaped to those in fig. 283, and four equal, little diamond shaped spaces in every intervening star, which little spots and the faces of the octagons are all that remain of the original surface of the glass, all the rest of the cobweb pattern being in brilliant facets that result from the intersections of the several, variously placed, series of parallel angular grooves in its composition. These and other varieties of facetting are produced on many differently shaped objects in these machines, and the working of the hobnail pattern, fig. 283, upon a square bottle with faces about 5 inches high by 3 inches wide, will serve to explain the methods followed. All the grooves cut upon these faces, it should be said, are of the angle of 45°, three-sixteenths of an inch wide and about the same in depth; the pairs of cuts are also three-sixteenths of an inch from center to center, with intervals of half an inch to the next pair of parallel cuts to leave the square portions of the original surface, which portions subsequently become octagonal or hobnail when the diagonal grooves remove their corners.

Fig. 285 indicates a facet cutting machine used and patented by Mr. Marlow, 1890. The upper part of the frame has a long horizontal slide with duplicate open cross slides traversed simultaneously to and fro along it by a mainscrew placed below, the reciprocation and extent of their traverse determined by a rod and tapets, fixed behind the horizontal slide, which move the strap lever and belt upon the driving pulleys of the mainscrew as in the ordinary reversing arrangement

used upon planing machines. The cross slides carry vertical slides upon which are strong spindles, provided with elongated driving pulleys between their bearings, that are driven by belts which pass through the cross slides from a long drum behind; and the lower ends of the spindles receive others, fig. 288, screwed into them, which are strung with the iron

FIG. 285.



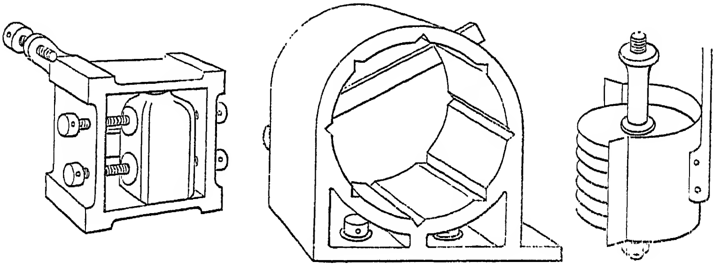
roughing and stone smoothing wheels. The vertical slides are graduated, and are raised or lowered to adjust the distance of the grinding wheels from a table below, parallel with the horizontal slide, by screws fixed outside them, actuated by bevel wheels upon their upper ends; and the corresponding bevel wheels mounted on the tops of the cross slides, are bored with plain holes and provided with feathers to travel along a grooved shaft, the length of the horizontal slide, which is turned to adjust the height of the grinding wheels by a pin wheel on its external end and a chain band to a similar wheel with a handle a little above the table below. Hence, the revolving grinding wheels travel and reciprocate continuously within any determined limits along the horizontal slide and, without cessation in these movements, may be raised or lowered to the positions at which they may be required to traverse the work.

The bottles are fixed in square holders which are placed

within two pairs of tubular collar heads bolted down on the table, one head of each pair being three-sixteenths of an inch lower than its fellow; the table travels on guides and is advanced towards the grinding wheels to give the depth of cut by a central screw beneath it, turned by a pin wheel on its further end and a chain band to a similar wheel on a spindle parallel with the screw, fixed to the side frame of the machine and terminating in a spoked handle close to that used for adjusting the height of the cutting wheels.

The nearly cubical cast iron holder, fig. 286, is open at both

Figs. 286. 287. 288.



ends, and the bottle, with the face to be cut slightly projecting beyond its front edges, is held within it by two screws with india-rubber covered ends on either side, whilst a fifth screw in the axis of the holder, which passes through a cross piece cast in the latter in the solid, bears against the opposite side of the bottle to that being cut to prevent any yielding to the pressure of the grinding wheels. The collar heads, fig. 287, have eight equidistant angular grooves which receive the four corners of the holders, so that the latter may stand within them with the bottles vertical, horizontal or inclined at 45° to either side; the extent of the advance of the holder through the collar head is determined by a screw in an ear at one corner of the former which bears against the annular face of the latter, and the holder is kept up to its work by a spring latch, fig. 285, which presses against its central screw the face of which latter is in contact with the bottle.

Although blown in true square moulds the entire surface of any side of the bottle is never perfectly flat, but the portions towards their ends being in the solid with the substance of the

glass at the neck and base, are always sufficiently true and these are used to adjust the bottles in the holders; the bottle is first rested by these extremities on the knife edges and the holder, fig. 286, is then passed down over it by its corners between the grooved uprights of the adjustment gage, fig. 289, after which it is gripped by the screws, and so remains when the holder is placed in the collar heads for all the cuts made on that one side, and it is readjusted in the holder, again resting on the gage, for each of its remaining sides.

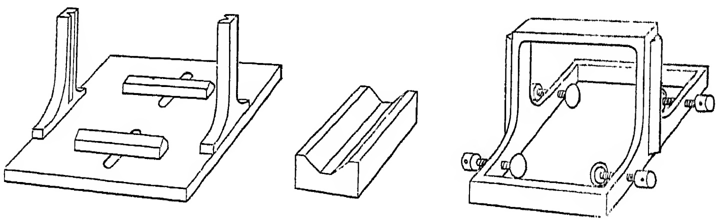
The spindle to the left hand of the machine, fig. 285, carries the iron roughing and that to the right the gritstone smoothing wheels. The former are 8 inches diameter and half an inch thick, turned flat upon their sides and to a double angle of 45° upon their edges, the cutting portion; they have plain holes and are simply strung upon the spindle, fig. 288, with washers three-eighths of an inch thick interposed, and the whole are brought up against a shoulder on the spindle by a nut and washer beneath them, they require no further fixing as the sand and water with which they are fed soon causes the whole to rust together as a solid mass; the stone smoothing wheels are turned to the same form and size, they are secured in the same manner and are fed with water.

Spindles with seven roughing and smoothing wheels are used for the four pairs of vertical and the seven pairs of horizontal grooves cut on each face of the bottle, made in the following order. The horizontal cuts are made first,—a holder is placed in the collar head 1 with its bottle vertical and the latter receives seven roughing cuts by the horizontal traverse of the iron wheels; the holder is then replaced by another in head 1, and is itself transferred to head 2, in which it stands three-sixteenths of an inch lower than it did in 1; here the first bottle acquires seven other cuts parallel with and in juxtaposition to the first series already upon it, and at the same time the second bottle acquires its first series of horizontal grooves in head 1. The first holder is next transferred to head 3 where the first seven grooves are smoothed by the stone wheels and then to head 4, where the second series of the pairs are completed in like manner; all four collar heads are thus continuously filled and the holders regularly transferred from one to the others, until a number of bottles have

received their pairs of horizontal cuts each upon one face; the remaining faces of the bottles are then treated in the same manner. Similar operations are then repeated with the holders turned one quarter round in the same grooves of the collar heads, so that the bottles now stand horizontally, and with the spindles lowered to place four of their wheels only in action, the bottles are roughed and smoothed with the four pairs of grooves which stand vertically upon them and at right angles to the seven pairs previously cut. Subsequently the spindles are mounted with nine wheels, their angular edges eleven-sixteenths of an inch apart, with which the single diagonal grooves are roughed and smoothed to complete the hobnails and their intervening facets; the holders placed at 45°, inclined first in the one and then in the other direction, and in the collar heads 1 and 3 only.

The constant equal supply of sand and water to all the wheels on the spindle presented difficulties; originally every wheel was separately fed through flexible tubes, but this and other methods tried were abandoned; at present the roughing wheels are surrounded to about three-quarters of their diameter by an iron shield, fig. 288, and the sand and water plentifully delivered on the surface of the uppermost wheel is thrown off by centrifugal force against the shield and thence deflects back to the second wheel and so on from one to the other throughout the series, which arrangement is successful. The sand and water after leaving the wheels falls through

FIGS. 289. 290. 291.



apertures in the table into a receptacle in the base of the machine, whence it is raised to be used over again in a manner which will be described.

The economy attained led to a further development of this system of glass facetting, in a series of machines patented by

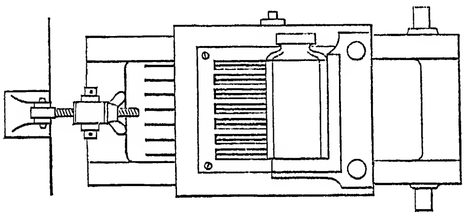
Mr. Marlow in 1892, now more used, in which the apparatus is simplified, the work itself serves as a portion of the guidance and, with all the same accuracy in results, the rapidity of production is still greater than before. The machines are used for numerous varieties of work, but it will be convenient to follow their operations upon hobnail cut bottles of similar dimensions to those already described, but octagon instead of square, that is, bottles with four wide connected by four narrower faces at the corners.

The first process is to grind all the eight sides of the bottles accurately flat, which is effected upon a true thick iron plate, about 3 feet in diameter, fed with sand and water and revolving horizontally on a spindle which passes through it to centers above and below. The bottle as before is first rested by the ends of one wide face on the adjustable knife edges of the gage, fig. 289, the grinding holder, fig. 291, is then passed down the vertical grooves of the former by its corresponding uprights, and two of the india-rubber covered screws in its base are tightened to secure the bottle; the two opposite screws remaining as first adjusted so long as the grinding is continued upon work of the same dimensions. The holder carrying the bottle is then slid down a pair of vertical grooves, of which there are four, two pairs to either side of the spindle, in a light oblong iron frame that is reciprocated upon a horizontal slide a short distance above the grinding plate, by means of a crank and a link to one of its ends; two operators work one machine who have barely time to adjust and fix each bottle in a holder before the face of that they have just previously put on the plate is completed, and the weight of the holders suffices for the pressure. For the narrow sides, the angular iron trough, fig. 291, replaces the knife edges on the gage, this supports the bottles by their wide faces already ground, the holder is passed down as before and the screws grip the bottle by its narrow sides which are then ground flat. The faces are subsequently smoothed by the same methods of holding upon a revolving stone in a second machine.

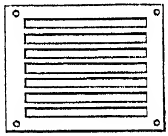
The machines for roughing and smoothing the angular grooves for the facets, figs. 292—294, are all of one model and nearly of one size; the iron and stone wheels, half an inch thick by about 22 inches in diameter, with the interposed

washers, are fixed on their spindles as already described, but the latter are horizontal so that the wheels revolve vertically, a much more favourable position as regards their feed with the sand and water which is delivered near to the top of their peripheries. A rectangular iron frame, like the sides of a shallow box without top or bottom, about 4 feet long by 18 inches wide, stands at an angle above the grinding wheels, its precise inclination regulated by a screw working in a nut pivotted to its upper end. A top slide, a second rectangular frame with a large central opening, is traversed upon the true upper edges of the inclined frame by means of a link pivotted

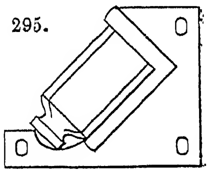
Figs. 292.



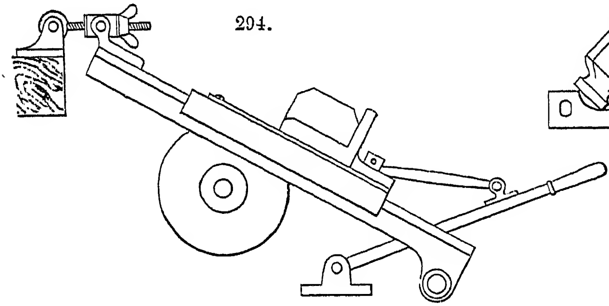
293.



295.



294.



to its right-hand side and to a hand lever below; and the square opening in this slide has a corresponding piece, fig. 293, fixed therein, called the *gridiron*, formed of a number of deep iron bars separated and parallel with one another, their flat upper edges all in one plane parallel with the axis of the grinding wheels, the peripheries of which latter pass between and project above the surface of the gridiron bars more or less as may be required by the depth of the grooves to be cut on the work. And lastly, fixed down by screws to the frame of the gridiron, there are various fence guides against which the

work is held by the left hand throughout its passages along the tops of the grinding wheels by the traverse of the slide impelled by the lever worked by the right.

A separate machine is provided for each different operation subsequent to the flat grinding of the faces of the bottles, which processes are conducted in the following order. The ends of every face at the top of the bottle next the neck and the neck itself are ground square across and to a regular ogee curve by a single grinding wheel of the section, fig. 300, fed with sand and water; the rectangular fence used is like that shown in fig. 292, with the longer of its two vertical faces at right angles to the direction of traverse of the slide. The bottle is laid first by each of its wider and then by each of its narrower faces on the bars of the gridiron, and is held in contact with these and with both faces of the fence throughout every traverse; the fence is permanently fixed down to the gridiron by its binding screws, but the holes through which these pass are elongated that it may be first adjusted transversely to the slide according to the length of the bottle and the amount that has to be ground off the ends of its faces. The extent ground away from the flat faces towards the axis of the bottle, in other words the projection of the rounded and concave edge of the iron wheel through the bars of the gridiron is determined by the screw at the upper end of the inclined frame, fig. 294, and these adjustments once made a number of similar sized bottles are rounded upon the neck ends of all their faces, effected by one gentle traverse of each face across the grinding wheel.

The facetting is commenced by cutting the two vertical angular grooves which run up the length of each edge of the narrow faces of the bottle; the machine has two grinding wheels separated by a washer, which project through the gridiron just sufficiently to give the depth of the grooves cut by their angular edges, the bottles travel in the direction of their length, the fence, fixed when adjusted for lateral position, has a longer sideface, and the two grooves on each narrow face are completed by a single traverse of the bottle. The four pairs of vertical grooves on the wider faces are next cut in a machine with four wheels, their angular edges seven-eighths of an inch apart; the fence is the same as that last used, but

is now allowed a free lateral traverse of three-sixteenths of an inch across the gridiron by the elongated holes for the stems of the screws by which it is attached, which latter are left slack. Four grooves are completed by one traverse with the fence pressed over to the right, and then the four others in juxtaposition to the first forming the pairs, by a second traverse with the fence pressed over to the left, the bottle held in contact with the side and end of the fence throughout its two upward and return journeys. The seven pairs of horizontal cuts which extend all around the eight faces of the bottles, are made in a machine with seven wheels spaced in the same manner as the last, the fence is that shown in fig. 292, and is shifted to right and left to cut the pairs, as just described. Lastly, a machine with nine wheels, their angular edges eleven-sixteenths of an inch apart, is employed to cut the two series of nine single diagonal reversed grooves, which pass through the centers of the crossings of the vertical and horizontal pairs, and take off the corners of the square spaces of the original surface the latter have left and leave these spaces octagonal or hobnail; a fixed fence with its upright faces at the angle of 45° to the traverse, fig. 295, is used for the one series, and after these have been cut on all the faces of the bottles it is exchanged for another sloped the other way to cut the corresponding reversed grooves.

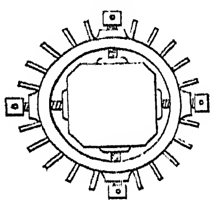
Apart from the absolute truth and regularity in the depths and disposition of the angular grooves and resulting facets, the gain in economy of time is considerable, and as regards the latter, it should be mentioned that the vertical, horizontal and diagonal roughing cuts on the bottles described in illustration of the operation of these machines, number together 30 and 40 upon each narrow and wide face respectively, or a total of 280 cuts upon each bottle, the whole of which are completed in half an hour, and by an expert workman in even less time. Lately still further acceleration in time has been effected by providing the different fences with the india-rubber covered screws to secure the bottles and making the traverse of the slides self-acting; so that instead of his having to move the slide and to hold the work in contact with the fence and gridiron throughout its traverse, the same operator can work two or three machines with which he has only to fix the bottles,

start the traverse, which is arrested automatically, and release and exchange them.

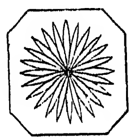
The roughing cuts may then be smooth ground in the same machines with the iron exchanged for stone wheels, but as the machine-made roughing cuts require no correction and very little to be removed from their angular surfaces to polish them, this operation is as often carried out by hand, every cut once traversed upon a blue mitre stone wheel revolving vertically in a frame similar to fig. 274; and the polishing upon wood wheels with putty and rottenstone powders for the completion of the surface of the facets is always done by hand.

The grooves may be angular, concave, convex, or reeds, &c., according to the forms of the edges of the wheels, and the

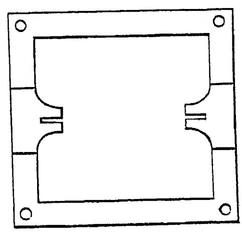
Figs. 296.



297.



298.



machines are also employed to place any of them in continuous parallel lines all around cylindrical, tapering, oval and other solids, with but slight difference in manipulation. The object is placed as before, and the slide is raised and then left stationary when the work has arrived over the axis of the grinding wheels and then, whilst still retained in contact with the fence and gridiron, the work is gradually twisted round upon its own axis by both hands until the grooves are cut all around it and return into themselves. Cylindrical or tapering forms are cut with spiral grooves by twisting the work round upon a fence which stands at an angle instead of square across the gridiron, and reversed spirals yielding diamond-shaped facets are produced on the same solid by cutting the second series of grooves with a fence sloped the other way to that used for the first.

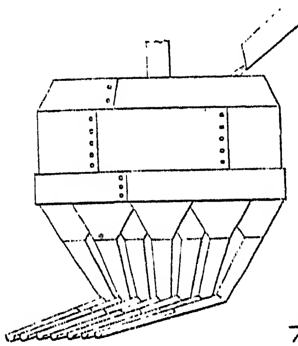
A further variety of work, the well-known star, fig. 297, usually cut by hand on the flat bases of bottles, goblets, and

other round and square objects, is produced on a gridiron-machine provided with a single angular edged wheel. The work is gripped by four india-rubber faced screws and centrally within the equidistant division holder, fig. 296, a deep iron ring with from 12 to 24 equally-spaced flat spokes or leaves projecting around its base; the fence is a square frame with notches on two of its sides to receive opposite spokes, and the holder is thus retained without play in either direction above the axis of the wheel. The holder is shifted round from pair to pair of its spokes and pressed down on to the grinding wheel, until the cutting is arrested by the work arriving in contact with the gridiron, and as the projection of the wheel through the latter gives the length and depth of the cuts, these are all both precisely alike and accurately placed. The cuts may be made to extend from the margin to meet at the center of the star, as in fig. 297, or to extend from margin to margin and cross the center, according to the position at which the slide is advanced and left up the inclined frame with respect to axis of the wheel; further varieties result from shifting the fence laterally to fix it with the notches parallel with but out of the plane of the wheel, or at an angle to it, the cuts are then tangential to a central space in the star, and lastly, all these latter ornaments may be accurately facetted by cutting them over a second time with the fence fixed to the opposite angle or to the opposite side of the wheel it previously occupied.

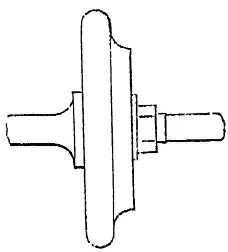
As already said, the ordinary simple method for the supply of sand and water does not suffice in machines where several wheels have to receive an equal and constant feed, that each may perform the same amount of work as its fellows. In the ingenious system patented by Mr. Marlow, a necessary complement to his glass-facetting apparatus, every separate machine is provided with a centrifugal distributor fixed above and behind it. This consists of a sheet-iron drum about 20 inches diameter and 14 inches high, with a series of from 2 to 9 funnels inserted around its flat base; the funnels terminate in tapering tubes bent a short way below and arranged side by side in one plane, fig. 299, and the upper sides of the smaller lengths of these tubes are cut away to leave them as open troughs, that the sand may not clog in what would otherwise

be a pipe of about three-quarters of an inch diameter; the extreme ends of the narrow troughs carry two projecting small wire fingers bent outwards, fig. 301, along which the sand and water trickles on to each side near the tops of the peripheries of the grinding wheels. The ends of the tubes stand at the required distances apart to be just over the edges of wheels as arranged on the spindles in most frequent use,

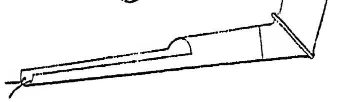
Figs. 299.



300.



301.



when the wheels are otherwise placed the tubes are separated in agreement with them by wooden wedges, and if all are not required, the flow from any one is stopped by a plug placed in the tube at the commencement of its trough portion. The sand and water falls through a pipe on to the surface of a flat iron plate, which is about one-third less in diameter than the drum, and revolves within it on the lower end of a vertical spindle, whence it is thrown by centrifugal force against the sides of the drum, and finds its way in equal quantities down the funnels. The supply to the distributor of every machine comes from the pipes of the funnels of larger but otherwise similar drums fixed above, one to every five or six machines, and the centrifugal plates of these larger drums are provided with wire sieves around their edges, through which the sand and water is thrown, and any pebbles, pieces of broken glass, and dirt retained. The copious flow of sand and water, the major portion of which does no work, falls from the grinding wheels into receptacles in the bases of the machines and flows away from all into a tank below; from this it is raised

by a sheet-iron tubular screw, formed of an inner and outer tube, 3 and 9 inches diameter respectively, with the space between them filled by a thread of sheet-iron of four inch pitch. The elevator screw stands and slowly revolves at an inclination of about 60°, and delivers into a tank on the floor above the larger drums, to which latter the sand and water flows through pipes and, with occasional additions, it is thus used over and over again.

SECT. III.—GLASS SUPERFICIAL DECORATION. SAND BLAST ENGRAVING.

The ornamented glass known as *enamelled sheet* in common use for glazing, has the one surface left plain and the other covered with the designs formed of dots, lines, small rosettes, fleur-de-lis, &c., placed separately or combined in patterns; the design is usually clear and transparent upon a ground or roughened translucent field, but is sometimes the reverse and semi-opaque, like ground glass, upon a clear transparent field. This decoration is produced in several ways; originally by a process of *matting* now but little employed; for this the surface is stencilled or printed with the ground or with the pattern, as the one or the other is to be obscured, with a semi-fluid, pasty mixture of the constituents of glass, which, when dry, is fused to the transparent sheet in an annealing oven, and this may be called enamel. To give a higher character to the ornament, the late Charles Holtzapffel, in 1844, at the request of Messrs. Chance of Birmingham, contrived a geometrical tracing machine which operated by one, two or four vertical tracers, that rubbed upon and removed the overlay in variously disposed lines from the sheet of glass lying below upon a large circular table, placed in rotation and other movements connected with those given to the tracers above, whilst independent motions could also be given to the glass and to the several tracers; the sheet of glass in this case was first entirely covered with the overlay, and the apparatus produced varieties of waved, rayed and other lines, straight marginal lines, and circular eccentric and looped epitroithoidal patterns, &c., up to twenty-four inches diameter, with the power of grouping all as desired upon the work.

The ornamentation first mentioned is now usually produced by biting in with acids, and in two ways which dispense with the subsequent fusing. In the one, the entire surface of the sheet is first ground with sand and water or with the sand blast, both of which procedures are described in these pages; the roughened white obscured *field* is then printed or otherwise covered with a mixture of beeswax and varnish tempered with tallow leaving the *pattern* exposed, and the latter is bitten in through the ground surface with mixed hydrofluoric and nitric acids which leaves it slightly in intaglio, bright and transparent as was the original sheet. Glass in two colours such as opal thinly faced with ruby is treated in the same way, the pattern resulting from biting through portions of the thin coat of colour down to the thicker sheet to which that has been fused. In the second method the surface of the glass is first frosted with hydrofluoric acid which leaves it translucent with much the appearance of ice, then coated as to the ground or as to the pattern with the resisting wax mixture and the acid reapplied, in which case the design is of the same texture and translucency as the field, but is distinct from its depth of intaglio; or else the field is stopped out on the frosted surface and the pattern is bitten in with the mixed acids to leave the design bright and transparent. The old trade name is retained although there is no enamelling, and, as inappropriately, the glass decorated by the second of the above methods is known both as double enamelled and as double ground sheet. By a third method much used for elaborate ornamentation the entire surface is first either sand blasted or treated with the acid, then entirely coated with the wax mixed with a larger proportion of varnish, which dries hard upon it, and upon this the pattern is stencilled or painted in a mixture which destroys the varnish and its adherence to the glass; when dry the lines and spots laid on in this second mixture are rubbed off by hand and bring away with them corresponding portions of the first, thus leaving the original surface of the glass, as regards the pattern, exposed for the action of the acids.

Lamp globes and other works blown in flint glass and small pieces of sheet are dipped in the acids, larger sheets are laid horizontally in shallow wood troughs covered with lead and then with gutta percha and the acid is dabbed on with sponges

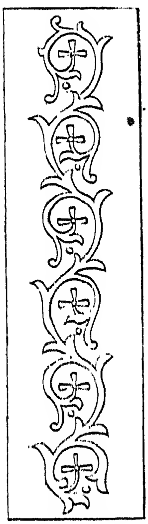
tied to sticks; all the work is subsequently well washed with water. The workmen sometimes protect their hands and arms with india rubber gloves, but the fumes which soon destroy such metals as the brass of the shop gas fittings do not appear to be especially injurious to health.

The intaglio quite inconsiderable upon sheet is carried to a much greater depth upon plate glass for tablets inscribed with letters, and for panels decorated with arabesques and borders which are often of great beauty; the work is executed on the back of the glass and shows through the exposed surface of the mounted panel. The outlines of the design are sketched on the glass with French chalk and all the interstices and the remainder of the surface are carefully painted over with one or two coats of a resisting wax varnish which is allowed to dry; the patches are then built up around their edges with wax until high enough to retain the hydrofluoric and nitric acids poured over the pattern. After a sufficient exposure, the glass is well washed with water and allowed to dry; all portions of the pattern which are of the required depth by this first uniform intaglio are then carefully stopped out by painting over with the varnish previously to a second biting in with the acid, washing and drying; this is many times repeated until some of the lines and curvatures are eaten in to so great a depth, that the scrolls and ornaments when viewed from the other side of the glass appear as if carved in relief. Finally either the whole of the back is silvered as a mirror or, for contrast, the intaglio is gilt and the remainder silvered.

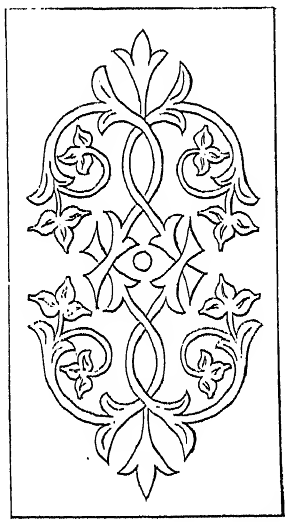
Another variety of surface decoration called *brilliant-cut glass*, lately introduced, has all parts of the design cut and polished on plate glass in intaglio of moderate depth, with such portions as leaves and the scrolls of arabesques in broad facets; the design is everywhere lustrous and may be in sharp contrast to a ground field, or it shines brilliantly when cut upon polished plate glass, or when cut through the skin of coloured faced glass it is brilliant and transparent white upon a coloured field. For a dull white field the plate is first ground with sand and water or sand blasted and the design is sketched in black outlines upon such surface, and on polished plate and on the smooth surface of the coloured faced sheets

the outlines are drawn with French chalk. The machine used is similar to fig. 274, except that the centers for the spindles of the cutting and polishing wheels used are mounted above the tops of the uprights so as to allow perfect freedom for the management of the sheet of glass applied above the wheel; the design is cut upon York and Warrington gritstones of great variety in diameter, thickness and in the forms of their flat, round and angular edges, which are constantly moistened with water. The smoothing is done with finer grained stone wheels or with wood wheels charged with emery, and the polishing

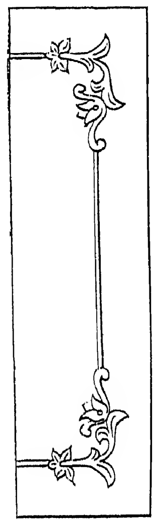
Figs. 302.



303.



304.



with the willow wood wheels and putty powder and sometimes with small circular wire brushes.

Pieces of plate-glass of moderate dimensions are applied horizontally, and traversed and twisted about on the top of the stone held in the hands, the operator constantly looking through the glass to follow the lines of the design to watch the progress of the cutting. Larger sheets, some of which measure more than 6 ft. by 3 ft., are suspended to the ceiling of the workshop to a counterpoise by slings of webbing passed around wood battens placed across their under sides; the slings are shifted on the plate as the cutting progresses and with the

mobility of the fixing above, enable the workman to lower and press the glass down on the stone and to move it to follow the curves of the ornament. The work requires considerable dexterity and the difficulties of cutting easily flowing curved lines of the character of those shown in figs. 302—304, and of repeating them in tolerable facsimile in their proper positions increase with the dimensions of the sheet under operation.

The edge of the stone is usually narrower than the width of the leaf or the facet it is used to cut, and these figures are ground by being shifted about lengthways and sideways upon it; straight lines for borders are cut with a stone of their intended width, and of a fairly large diameter in order to diminish the decrease in depth of cut, due to the circular form of the stone, which otherwise occurs at their extremities, an effect that is also evaded, as in fig. 304, by running these ends into some small ornament the depth of which is equal to that of the main body of the line. Ribs and lines of division in the scrolls of arabesques and veins on leaves, indicated in fig. 303, are ground with sharp angular-edged stones or emery-wheels and to a greater depth after the first grinding of the design, and are left untouched for the effect of their contrast to the portions subsequently smoothed and polished. Similar lines are sometimes cut all around the outline of the design for emphasis, but these are generally polished. The designs for brilliant cut glass are also readily and exactly recessed in the surface of the sheet by the process next described, as a preparation for their subsequent cutting, smoothing and polishing.

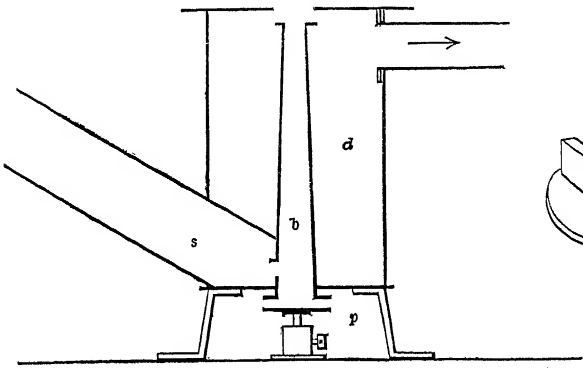
The sand-blast process invented by Mr. B. Chew Tilghman of Philadelphia, 1870, already noticed in respect of some of its applications in previous chapters, is extensively used for glass surface decoration and embosses the pattern on the ground with effects similar to those of the older methods of matting and enamelling. The results are produced by a stream of sand projected by air or steam, the particles of which rapidly roughen or pit by their impact the surface of the glass, metal or other substances against which they are directed, except all portions covered by some semi-elastic coating, and these portions may be either the pattern or the ground as the one or

the other is required to be left clear or frosted. The late Professor Tyndall describing the principle of this curious action in a lecture delivered at the Royal Institution, used the Sphynx of Egypt as an illustration; he said—"The neck is partly cut across, not, as I am assured by Mr. Huxley, by ordinary weathering, but by the eroding action of the fine sand blown against it. In these cases nature furnishes us with hints which may be taken advantage of in art; and this action of sand has been turned to extraordinary account." With respect to the sand-blast process he says—"Every little particle of sand urged against the glass, having all its energy concentrated on the point of impact, forms there a little pit, the depolished surface consisting of innumerable hollows of this description. But this is not all. By protecting certain portions of the surface, and exposing others, figures and tracery of any required form can be etched upon the glass."—"A fraction of a minute suffices to etch a rich and beautiful lace pattern. Any yielding substance may be employed to protect the glass; by immediately diffusing the shock of the particle, such substance practically destroys the local erosive power, and the hand can bear without inconvenience a sand shower which would pulverize glass. In fact within certain limits, the harder the surface the greater is the concentration of the shock, and the more effective is the erosion."

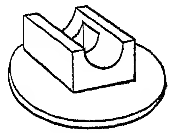
The sand used in this country comes from Reigate; it is first sifted to cleanse it from impurities and then again to separate it into two or three degrees of fineness for the coarser or more delicate varieties of etching. Upon large sheets for glazing the pattern is stencilled or imprinted in one of the glutinous mixtures to be afterwards described, the design is then left clear and bright and the field is alone frosted by the action of the sand, borders and central ornaments are stopped out in the same manner, but when the field is to be transparent that is entirely protected and the pattern is left uncovered. The sand stream is impelled up a vertical pipe by a continuous current of air and strikes the glass which is slowly traversed a few inches above and at right angles to the orifice through which it is delivered, and many machines have several such delivery pipes placed in a line and a little distance apart from one another. The sheets of glass are sometimes propelled

lying on the open frame of the machine, but the latter is more often provided with a travelling table with adjustable slits and openings which may be arranged to roughly correspond with the pattern, and this with the glass lying flat upon it is moved along and arrested by mechanism for a few moments from point to point as the openings arrive above the jets. The current of air is given by a large fan which supplies several machines, and is delivered at a low pressure not exceeding one pound to the square inch.

Figs. 305.



306.



Machines of far less complex character indicated in section, fig. 305, are also used at the London Sand Blast Works for pieces of glass of all sizes up to those which can be held and manipulated by two operators. A sheet-iron drum, *d*, about 2 ft. diameter, closed above and below and raised from the floor on short legs, carries a vertical tapering iron pipe of oblong section *b*, two by three inches at its upper end, this latter is a little below the flat cover of the drum which is pierced with a four-inch central aperture, and the lower end of *b*, passes through and is secured air-tight to the bottom of the drum. The dry sand is supplied by gravity from an inclined trough *s*, closed in on all sides but connected to the lower end of *b*, by an adjustable valve through which the sand falls on the surface of the plate *p*; thence and as it continues to fall it is carried up the pipe *b*, and strikes upon the glass held down and moved about on the flat cover of the drum; after striking the glass the larger portion of the sand is carried

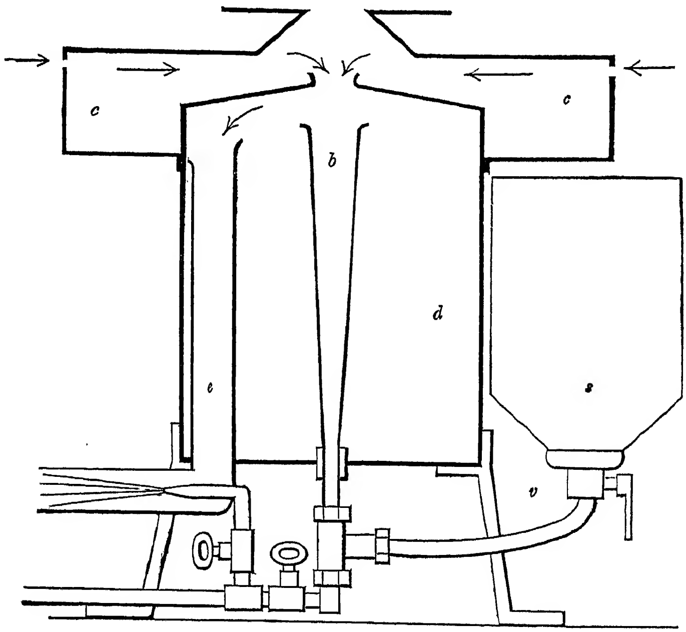
away along the exhaust pipe *e*, and the residue falls to the bottom of the drum from which it is cleared from time to time through a door at the side. The stream of sand is impelled or sucked up the pipe *b*, by a current of air of about three-quarters of a pound pressure, created by an air-pump exhaust engine connected to the large pipe *e*. This machine which consists of an ingenious reciprocating fan with a system of air valves in its blades, patented by Mr. J. E. Mathewson, 1877, establishes a constant partial vacuum in the drum *d*, and the external air rushing in between the lower end of the blast-pipe *b* and the plate *p*, carries the sand up with it, and the plate *p*, is raised or lowered to regulate the ingress of air. The exhaust pipes of numerous machines all join a long sheet-iron tube which runs around the walls of the workshop to the exhaust engine, placed in another room, on the road to which an intercepting shield and trap collects and ejects the passing sand and prevents its travelling on into the fan.

In using the apparatus the workman covers the aperture in the head of the drum with a square piece of felt held in his left hand, under a corner of which he then slips one edge of the work with his right, abandoning the felt so soon as the glass covers the hole; the felt is re-applied as the work frees the aperture and is kept on by a weight during all short intervals to prevent the upward escape of the sand, and the latter is cut off by the valve in the trough from any machine temporarily unemployed, the exhaust being always in action upon every machine throughout the group. For labelling chemical and other bottles a shield, fig. 306, a round plate with a concave or rectangular trough above, the size of the exterior of the bottle and pierced with an opening the size of the label stencilled or printed on the latter, is placed on the top of the drum. The sharp grains of sand act with surprising vigour and rapidity, the letters or pattern cut on the under side are almost immediately visible through the sheet of glass and are completely and evenly cut in a few seconds, whilst apertures, holes and slits for ventilators are readily pierced through sheet glass by a few minutes' continued exposure, nevertheless the hand may be held in the same sand blast without the smallest inconvenience.

Currents of dry air produced as described or sometimes by

compressed air are more general, that the sand also may be dry, because moisture sometimes interferes with the integrity of the more delicate filaments of the protecting overlays fixed on the glass, which overlays are necessarily made of ingredients that will readily wash off the glass after it has been frosted; except for these reasons simple jets of steam serve equally well and dispense with the exhaust engine. With this view Mr. Mathewson has patented a machine, very similar to that last described, with a steam blast from which nearly all the moisture is extracted just before the sand strikes the glass.

Fig. 307.



In this apparatus, fig. 307, the sheet-iron drum *d*, has a central aperture in its conical roof and is surrounded at its upper end by a second drum or casing *c*, the surface of which latter extends upwards and forms the table for the work; and *c* is pierced with a series of numerous small holes all around close to the upper edge of its periphery. The sand in a separate receptacle *s*, its exit controlled by a valve *v*, falls through

a tube and is delivered at the lower end of the trumpet-shaped blast pipe *b*, at a point just above the junction of the latter with the steam jet. A large exhaust pipe *e*, runs down within one side of the drum and is bent below it at right angles, where it is provided with a small steam jet; this last and that for the sand both proceed from the same supply and are separately controlled by stop cocks. To put the apparatus in action, steam at from 20 to 30 lbs. pressure is first turned on at the lower stop cock, then the sand, and as soon as this has provided a full sand blast the hole in the table is covered and the second stop cock is opened to create a downdraught in the exhaust pipe *e*; the dry external air thereupon entering on all sides through the holes in the casing *c*, travels in the path shown by the arrows, crossing the sand blast in all directions above the mouth of the drum *d*, and so away down the exhaust pipe. The continual supply of dry air carries away sufficient moisture from the steam without diminishing the force of the sand blast, but the machine in time becomes too hot for safety to the glutinous pattern, its use is then intermitted and the work continued on a second similar machine beside it.

Various quick-drying glutinous mixtures, semi-elastic but moderately tough, that are also easily removable, are placed on the glass in several ways. A viscid composition of glue, dextrine, glycerine and any powdered colouring matter is painted on by hand, or for many repetitions of the same design is printed on from wood blocks, or pieces of stout paper cut out to letters and designs are dipped in this or some similar mixture and attached to the glass by rolling and rubbing down. Similar materials are applied by stencilling; for the more delicate designs the stencil plates are cut out in tinfoil, and these when carefully laid down and smoothed out upon the glass have all their interstices filled in with the dextrine with a palette knife, after which the perforated sheet of tinfoil is raised at one edge and gently stripped off to serve again. Another method is to print the design from engraved plates or blocks with a thick glutinous ink on thin paper, the impression is transferred face downwards to the glass, rubbed down and allowed to dry upon it; the sand then destroys all the thin paper between the printing and attacks the glass where not protected by the thick ink. For common work, notice and commercial

tablets, more deeply cut matrices are used. These when warmed and oiled have all the design filled in with a palette knife with a tepid paste of gutta percha, wax, resin and turpentine, and after the surface of the block has been cleaned, a sheet of paper is rubbed down upon it with a felt roller; the paper when stripped off brings all the paste with it and is immediately transferred to the glass and lightly pressed down with the hands, after an interval the paper is in turn removed from the design and any damaged edges of the hardening paste left on the glass are repaired. Numbers of advertisement tablets, oblong pieces of clear or opal, faced with a layer of some coloured glass, are very economically produced in this manner. For example, such a tablet often has a broad white label running diagonally across it carrying the principal word in coloured letters, the ends of the label joining an ornamental border of lines and scrolls also in white and carried all around the margins of the tablet, the coloured triangular spaces between the border and the label having the subsidiary words of the notice in white letters. For this all the intended coloured portions of the design are sunk and the white are left of the original surface of the matrix, and the latter once provided, the pieces of glass covered with the resisting material taken from it are each completed by the sand blast in a few minutes. Some of these tablets already most effective, are further elaborated by the acid-bitten decoration previously described, executed from behind and showing through the shallow intaglio produced by the sand blast on the front, the backs and the work bitten in upon them are all left clear or they are partially or entirely gilt or silvered.

Very delicate beautiful ornamentation for panels, made of a sheet of white with one or more layers of coloured glass fused to its surface, used for screens, etc., results from stretching and fixing down pieces of Nottingham lace curtains, after dipping in the diluted dextrine, on the amber, gold or other coloured side of the glass. The design left in colour upon a nearly or perfectly white ground, according to the time of exposure to the sand blast, is perfectly reproduced but with a curious advantage; the most delicate separate threads, the loosely and the more thickly woven portions of the lace all closely adhere to the glass and leave corresponding copies of the full colour,

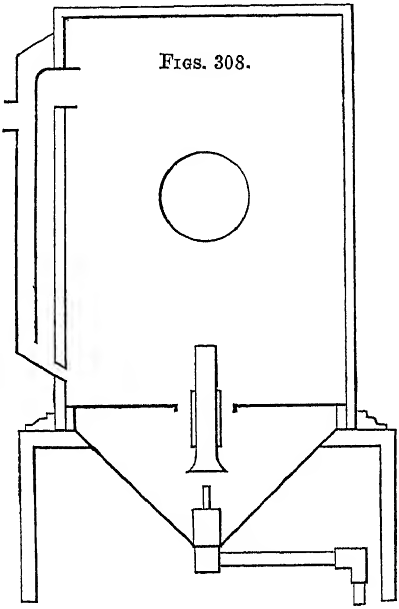
but at all parts of the design where the threads although collected are less closely woven together, the finely sifted sand employed finds its way through here and there and thus diminishes the depth of colour, hence, the result produced on the glass is more delicately graduated in shades of colour than was the original lace in depth of light and shade. The preparation of designs by hand on paper or on the actual sheets of glass is well worth the attention of the amateur, and the subsequent application of the sand blast can readily be obtained.

Glass or metal vases, caskets and similar solids, complete or in pieces before they are put together, are treated with the sand blast to produce patterns of the original polished surface on a dead ground, or to matt or frost the ground between engraved, incised or embossed portions previously executed. The machine for this class of work has the blast pipe enclosed in a large wooden box, glazed in front and with holes in the sides provided with sleeves with elastic wrists for the arms, and the orifice of the pipe stands some six inches above a false floor of coarse wire netting. The several pieces placed on the netting are picked up one by one and held and twisted about in the sand jet and replaced as each is completed, the used sand falling through the wire netting into a large receptacle formed by the lower half of the box.

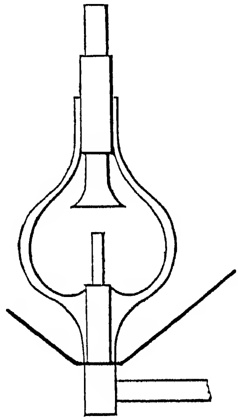
An inexpensive but effective form of sand-blast apparatus, fig. 308, has been patented by Messrs. Coldwell and Davies, 1889, which is worked by a foot bellows contained within its pedestal and is used for small works in gold and silver, electro-plate, glass, etc.; it gives a beautifully even frosted ground and from its facilities brings the practice of this class of decorative art within the reach of the amateur. It consists of a rectangular box 9 or 12 inches square by 15 inches high, the front glazed and the sides with arm holes and sleeves as lately described; this stands within a rebate and is removable from a shallow square wood case provided with a funnel shaped metal basin which contains the sand, and this second box is fixed on a square pedestal that encloses a double action bellows with a foot treadle projecting from the base in front; the whole apparatus being about 5 feet 6 inches high. The pieces to be frosted are placed on a floor of wire netting fixed

above the basin and are picked up and held by one or both hands for a few minutes in the sand blast and redeposited as completed. The basin is filled with sand which covers up the nozzle of the air jet and the lower half of the delivery pipe, shown detached on a larger scale, fig. 309; the former has an aperture of three sixteenths of an inch diameter and rises through the basin, the cylindrical delivery pipe of five eighths

Figs. 308.



309.



of an inch bore slides within a ring, so that its trumpet shaped lower end may enclose the air jet or be placed at varying distances above it to regulate the quantity of sand projected; and the air pipe is bent twice at right angles below the basin to prevent any sand from finding its way downwards into the bellows. The sand carried up by the continuous stream of air strikes against the work and the roof of the box and falls back into the basin; but the air has an outlet opposite the glazed side of the top box in the form of a tube which enters near the roof and runs down outside, the external portion of the tube enclosed within a casing with an aperture at its upper end. Any sand carried off by the air falls from the lower end of the tube through

a slit in the side of the box back into the basin; practically none escapes but all is used over and over again, a small quantity being added from time to time. Surfaces to be gilt are first sand blasted; and the particles removed from gold work are readily recovered by treating the sand when that contains sufficient to be profitable.

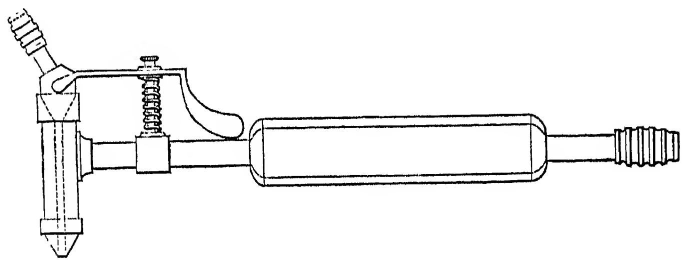
Engraving upon stone and upon copper and steel plates for printing, by far the most remarkable application of the sand blast, arose in 1889, with the late Mr. J. L. Mills, whose patents are now worked by Messrs. Gilbert Whitehead & Co. of London. To aid explanation, it should be premised that, in ordinary lithographic printing, the stone previously reduced to a level smooth surface has the design drawn thereon with a greasy chalk or ink, which materials partly sink into the stone but also leave the design, to an almost inappreciable degree, in relief upon it; and that when printed from, the surface of the stone is kept constantly wet with water so that it repels the printing ink, applied with a roller, from all parts except the greasy lines of the drawing on which the water cannot stay; hence these lines alone receive the ink and are reproduced in the impression. In sand-blast lithography this may be said to be reversed, as, with certain small exceptions for the purposes mentioned later, the *entire* surface of the stone is first impregnated with grease, so that if inked it would print a uniform black, and this surface is then eaten away by the sand blast to entirely remove the grease from the portions that are not to print, to partially destroy it upon those that are to give the differing tints, and to leave it intact on those which are to print black. The surface of the stone is itself more or less penetrated and removed with the grease by the action of the sand blast, for portraits and drawings usually to a very slight depth, but for coarser work to a greater, the character of the former surface differs comparatively little from that of an ordinary lithographic stone, the latter rather approaches the quality of type; in all cases the remains of the original greased surface alone print, and the stones are wetted with water every time before they are inked for each impression which is taken in the ordinary press.

Copper and steel plates for printing have brightly polished true flat surfaces, upon which lines and dots of varying widths, depths and contiguity are incised with the graver, etched with acid or produced in mezzotint to contain the ink, all untouched surface of the plate not printing and giving the lights; the three methods of pure line, etching, or mezzotint are used separately, but now, all three are also frequently employed on the same plate. In the printing, the entire surface of the plate is inked, then the ink is wiped off and the surface cleaned and, lastly, polished with whiting rubbed on with the palm of the hand, the ink then remains only in the intaglio from which it is withdrawn and transferred to the paper by the pressure of the rolling press employed in taking the impression. Copper and steel plates prepared by the sand blast do not differ from the above, the ink is retained in the intaglio, the innumerable little depressions made by the impact of the sand or emery, and the plates are inked, cleaned and polished and printed from, like all produced by the older processes. Finally it should be said that sand-blast engravings possess all the same qualities of drawing, light and shade, vigour or delicate refinement of the best works on stone, copper or steel, the results of the more usual methods; whilst in these respects they leave nothing to be desired, their further merit lies in the extraordinary rapidity with which they are produced, comparisons upon which last point would read like exaggerations.

Lithographic stones long quarried and seasoned are more brittle in substance and are preferred for the action of the sand blast. After being ground and polished truly flat the surface is lightly but uniformly impregnated with a mixture of oil and the lithographic ink used in drawing, and is subsequently rolled with a thin coat of asphaltum or ordinary brunswick black varnish, which leaves the surface a uniform chestnut brown, the coloured varnish being used solely to allow the artist to watch the growing effects of his work as the numberless punctures made by the sand or emery show the lighter tint of the stone more and more through the colour. Copper and steel plates when smoothed and polished receive no other preparation than a similar coat of the pigment varnish for the same purpose.

Sand, powdered glass, both sifted to sizes, emery powder from fine grinding to that which will pass through a sieve of 20 apertures to the inch, Tilghman's iron sand and small steel shot are all employed, the emeries, perhaps, more than the other materials, and all are projected by compressed air through the *sand pencil*, fig. 310, which, after experience with many other implements, is now the only instrument used, differing only in the size of the orifice through which the sand or other material is blown.

Fig. 310.



The sand pencil, fig. 310, consists of a brass pipe about a quarter of an inch bore and nine inches long, with a square wooden handle at the middle of its length; the compressed air is admitted at the lower end through a length of flexible india-rubber tube which comes from a small reservoir, constantly replenished with air at from 15 to 30 lbs. pressure and provided with a tap to regulate its egress. The opposite end is fixed to a short transverse pipe of larger diameter, which is contracted at one end by a hollow conical mouthpiece and stopped by a cap at the other. The cap is bored and carries the delivery pipe which is parallel throughout and extends to nearly reach the orifice of the hollow cone of the mouth piece, the one is exactly central to the other so as to leave a small annular space between the two, and there is a larger air space all around the delivery pipe between that and the transverse pipe its casing as shown by the dotted lines; the delivery pipes vary in bore from that of a small pin hole to about a quarter of an inch in diameter, the conical nozzles correspond, but leave a rather increased annular space around the orifices of the larger sizes. Externally the cap is hollowed out as a funnel, above which it carries a short metal pipe to which the sand or emery is

supplied by gravity through a flexible tube from a receptacle fixed to the ceiling; the india rubber tube and the short metal pipe are always full but the supply is regulated or cut off by a plate stop at the base of the latter, after the manner of an old-fashioned powder flask, worked by the thumb pressed on its lever end just above the wood handle, the sand falls in the funnel and down the delivery pipe at the end of which it is caught by the air which rushing out of the nozzle carries the sand forcibly with it.

The instrument is grasped by its square handle held sloping forwards, so that the nozzle inclines downwards and the stream of powder is directed on the stone or plate at an angle of about 45°, and the two flexible tubes are sufficiently long and slack to allow it to be traversed in all directions. The stream of sand as it leaves the nozzle remains parallel for a short distance and then spreads out into a cone of rapidly increasing diameter, the separate grains of sand or emery, at first a compact mass, diverge more and more, but are always distributed throughout the cone in uniform attenuation; hence when the instrument is traversed with the nozzle close to the stone or plate the powder cuts a line of a width equal to the diameter of the orifice through which it is projected, at a little distance one wider and less deep, and at increasing distances, no longer lines but more and more widely dispersed punctures the sufficient repetition of which yields every degree of dark to light tint. The artist is not only absolutely unfettered in his manipulation but he records his conceptions directly on the stone or plate, for he can pass instantly to all desired effects from sharp lines to the broadest shading without change of sand pencil, by simply holding the latter close to his work or at any distance up to about 18 inches from it; moreover, he can employ the quality of powder most in accord with the delicacy or boldness of the effects desired, he can allow the escape of a full or diminished supply and he can vary the pressure and regulate the quantity of the air by which it is projected.

The embrowned surface is usually marked with a partial or complete outline as a guide for the earlier direction of the sand blast. For letters, patterns or borders of arabesques or lines, in which rigid precision is the first requisite, the outlines drawn on paper are traced in coloured chalk and transferred

by rubbing to the stone; for copies of figures or landscapes the main outlines only are transferred, but for higher class work, copies of portraits and original drawings, the artist does much less and only indicates the pose, features, hair &c. in chalk on the brown surface exactly as he would with charcoal on a canvas, that in like manner he may remove and alter these lines until content with their drawing and arrangement.

The author was privileged to watch the production of a life sized head on stone, an original work executed in classical taste, and his constantly increasing admiration was divided between the talent and deftness in manipulation and the facilities and extraordinary rapidity of sand blast drawing; the following particulars will be of interest. The large stone slab set up on an ordinary easel in the studio, had the outline of the female head in three-quarter view and the positions of the features and clustering hair, lightly sketched upon it in red chalk, and, as a final preparatory step, the artist cut with scissors in foolscap paper a counterpart of the cheek and chin which he intended to be in light against a future gradated background. With the sand pencil fed with emery and the paper guard held in position on the stone under the points of the fingers of the left hand, he commenced by traversing the jet for a few moments up and down the edge of the paper, and then in all directions, lingering more or less over the different features, throat and hair, going and returning from one to another, the pencil sometimes closer and sometimes further from the stone, returning once and again to the paper outline, after which that was abandoned, until, with marvellously rapid growth, the head and features, even to the ear, were perfectly *ebauché* in light and shade standing out clear from the background the, as yet, untouched brown surface of the stone. The work that had been thus far executed in less than half an hour, could hardly have been produced by two days labour had it been drawn in chalk in the ordinary manner, it presented all the character of mezzotint or of a careful chalk drawing, due to the varying dimensions and dispositions of the innumerable little portions of the original brown surface that remained, and would print, and the equally innumerable and varied little pits or depressions made by the impact of the particles of emery which gave the lights, and

would not print; a *pull* or trial impression on paper made to more perfectly judge of the effect gained, now or hereafter, therefore, is always an exact facsimile of the work on the stone at any stage of its progress.

To continue and gradually complete the drawing from this first light and shade, numerous large or minute portions must remain of the depths of tone they have already attained, still more must be reduced to a lighter, and some, the high lights, to absolute white, and the artist now has many expedients by which he absolutely controls the action of the emery to his will. Among these,—to leave portions of tones already obtained upon those to be made lighter, so as to meet the latter more or less abruptly as for the eyebrows or lips, or still more strongly, as in the shadows of the ears or nostril, or, into which lighter tones the stronger are to gradate and merge, as in the roundings of chin or brow, or still more delicately as on the cheek. For all these and indeed continually throughout the completion of his drawing he covers the portions to be preserved with overlays, some entirely and others partially impervious to the action of the jet, made by simple thick strokes or washes of ordinary chinese-white body colour, laid on with a sable brush.

Returning to the progress of the head,—the artist next freely planted numerous such strokes of the pigment all about the features and hair, some left as simple touches, whilst others as they dried had further strokes and blots superposed until irregularly built up to thick impasto, the current of air through the pencil, but with the emery cut off, always playing on the stone to assist their drying. These rapid bold touches were followed by a brief reapplication of the emery jet, the instrument delayed a few moments upon each and traversed from one to another four or five inches from the stone, and then all the white was swept off with a wet sponge to observe progress; similar operations constantly repeated refining the drawing to its completion. When not designedly too thick, a single such wash of the pigment is more or less penetrated by the emery, and is employed for the more delicate gradations, as on the cheek, but the blots and strokes built up to impasto are penetrated at their thinner edges and less and less to their thicker impervious portions, and exactly supply the more abrupt transitions as for an eyebrow or a shadow, with the

result that in all, the actual feeling of the artist as given by his touch with the brush is instantly recorded and with supreme exactness on the work by the emery.

Again, as to both delicacy and facility of clear sharp outlines obtained by the paper guard previously mentioned. It is hardly necessary to say that such an outline in bright light is always too hard against a dark background, and in all painting and drawing has to be softened or rounded by tenderly working the colour of each into the other throughout its length; this labour is instantly accomplished by the emery or sand jet, which, held fairly close and passed along the line operates equally to either side and just sufficiently reduces the tone of the edge of the background to destroy all hardness.

Definite points or spots of actual black as for the pupils of the eyes and for the depths in some shadows, are preserved intact by painting their overlays in a thicker impervious pigment mixed with varnish on the original brown surface of the stone before that is touched with the jet, and similar sharply-defined portions of any tint during the progress of the drawing, as for parts of a diadem, are retained unimpaired in the same manner. Conversely, actual white for high lights on tints or black are made to precise shapes by painting impasto around them, or for sharper edges by cutting their counterparts as holes in paper held down on the stone, so as to prevent the emery from penetrating except through these apertures.

Large masses of pure white in drapery, or very numerous small spots as in lace or portraiture costume, and always in letters and for the white in the details of patterns and borders lithographed for commercial purposes, have the requisite stopping out made by painting or otherwise marking on the pure polished stone before it is impregnated with the oil in a gum varnish impervious to the latter and to the emery, after which the remainder of the design is carried out with any or all of the expedients that have been mentioned; hence as all parts first stopped out have received no oil, although they remain of the original surface of the stone, when printing later they absorb the water and cannot take the ink and, therefore, leave their counterparts white on the impression.

Flat or perfectly even tints and others gradated from dark

to light, used for backgrounds, are obtained with ease; for the former, the jet is controlled to play at the same distance from the stone and for a longer or shorter but precisely similar period, according to the tint desired, over every portion of the space to be covered; gradated tones result from a partial gradual cessation of the traverses of the jet. As aids, the stone is placed in a wooden trough like three sides of a shallow box, stood on the easel; the artist rests his mahl stick across the edges and traverses his hand with the sand pencil at an even pace along it, then a little lowers the stick parallel with its first position and retraverses it as before, and so on from top to bottom of the stone. Once so traversed the previously untouched surface prints nearly black, more or less as the jet has been held closer or further from it, many repetitions give the lighter tints and when still more numerous, so light a uniform tint that it is used to exactly imitate the plate mark to give an impression from stone the resemblance of one taken from a steel or copper plate. For gradations the repetitions of the traverses are gradually increased from the dark to the light side.

In sand blast engraving on copper and steel the expedients and general manipulation are virtually the same as for stone, but, from the superior quality of the surfaces of the plates, the results are, perhaps, still more remarkable in their exquisite finish. An example is given fig. 311, an autotype reproduction of a steel plate measuring 19 by 13 inches, entirely executed with the sand pencil and emery of different degrees of fineness.

The polished plate receives no preparation beyond that of a thin coat of the brown pigment, used that the colour of the metal showing through its perforations may permit the artist to watch his effects in their earlier stages; the subsequent progress is observed by more frequent trial impressions than with stone. The main difference between work on copper and steel and stone is, that in the latter all untouched portions of the original surface print, in the former it is the reverse, all the more or less untouched portions give lights and the indentations retain the ink and print, and to a greater depth of colour according to their size, depth and contiguity. This however does not affect the artist, as the effects he produces

st drawing with the sand blast are as plainly visible on one material as the other.

ne sand pencil and the coarser pulverizing materials are ely employed for stones for printing works of a far bolder acter than hitherto mentioned. Among numerous posters ywhere under observation that have been executed with it, e from drawings by artists of renown, one issued by a ninent firm represents two maid servants and a sweep, life the background portions of buildings and perspective ance, the whole surrounded by an ornamental border or ne, excellent alike in drawing, textures and light and le. This large poster is composed of nine sheets of paper 60 by 40 inches, pasted up together to give the complete are. It was executed in the same studio and with coarse ry, but otherwise with the same means as the delicate l plate, fig. 311; and it has another point of interest, ortunity was taken to ascertain in how short a time it was ible to complete it. The nine stones having been prepared heir brown colouring, the artist commenced and entirely hed the design spread over the whole number in the edibly short space of rather less than nine days.

has lately been proposed to employ a similar but larger l blast pencil and sand for cleansing the begrimed soot and ther stains from our public buildings and, as the action of sand could be perfectly confined to the removal of the osit of soot without damage to the stone it hides, it is quite sible that the idea may be tried and prove successful; eover, as mentioned in a previous chapter, the sand blast lready applied to a somewhat analogous purpose, that of ning off and refacing the edges of grindstones.

CHAPTER X.

LAPIDARY WORK.

SECT. I—SLITTING, CUTTING, AND POLISHING FLAT AND ROUNDED WORKS.

THE term lapidary work, although apparently applicable to all the various modes of working or finishing stones, is nevertheless restricted in technology to the cutting, grinding, and polishing of gems and small stones, and some other materials, principally for jewellery or mineralogical specimens.

The lapidary never employs abrasive materials in that which may be called their natural or unprepared state, in the manner that the grindstone or oilstone are employed for restoring the edges of tools; but he uses the several abrasive materials in a pulverized form, and upon revolving discs of metal and other materials by way of vehicles, thus constituting artificial grinders, which are called *mills;* thus we have the slitting mill, the roughing mill, the smoothing mill, and the polishing mill, all generally of metal; but for soft stones the smoothing mill is sometimes a plain disc of willow wood or mahogany. The polishing mill is sometimes composed of a spiral coil of list placed on edge like the leaves of a book; sometimes of bristles like a brush, or of wood covered with buff leather, which several apparatus are fully described under the head WHEELS, in the Catalogue of Abrasive Materials at the commencement of this volume.

The succession in which these mills are employed by the lapidary for substances of different degrees of hardness, is also briefly explained in the Catalogue under the three heads, ALABASTER, CARNELIAN, and SAPPHIRE, stones that differ considerably in hardness and have therefore been selected as general examples; under each head is appended a list of such gems and other substances as are worked by the lapidary in a similar manner. The principal peculiarities in the methods

of working other stones, are also mentioned in the catalogue under their respective names, as Agate, Amber, Avanturine, &c.

The general remarks offered under these heads, have greatly abridged the observations to be submitted in the present chapter, which will be confined principally to a description of the apparatus, and the details of manipulation, which are nearly alike in working corresponding forms in either hard of soft stones; the principal difference being that the polishing mills are composed of hard or soft materials, according to the degree of hardness of the substances to be polished.

The apparatus commonly employed by the practical lapidary will be first described, followed by some account of the methods of producing the more usual forms met with in lapidary work, and the modifications in the apparatus generally employed by amateurs for similar purposes will be subsequently adverted to.

All the mills of the lapidary revolve upon vertical spindles or axes, so that the discs travel horizontally, the reverse of the position employed by the cutler, and usually by the glass and gold cutters, although the two latter classes of artizans are in the frequent habit of working analogous forms, and in some few instances, as in the case of cutting facets on amber beads, the gold cutters are considered to excel the ordinary lapidary.

Flat and rectilinear works are, in all their stages, ground and polished upon the broad flat surfaces of the mills, which revolve with moderate velocity, and the work is held almost stationary, much the same as in lapping flat works in metal.

Convex works are roughened on the ordinary flat roughing mill; but they require to be continually rolled about to bring every part in quick succession into contact with the mill or disc, as holding the stone at rest would inevitably wear down a flat place. Convex works in soft substances are generally smoothed on a wooden disc, which, from its elasticity, and also from its surface wearing slightly rough, or fibrous, yields a little to the stone and does not meet it so rigidly upon one

mathematical line as the unyielding metal disc. The list mill, from its pliancy, is also very well adapted to convex works, and is commonly used for glass; the leather and brush mills are also occasionally employed for rounded works.

Concave works necessarily require mills that will penetrate into their cavities; the rounded edge of the disc is in this case used somewhat as a glass cutter would grind a transverse flute, except that the work is held at an angle instead of parallel with the axis. But when the cavity is required to be spherical, or curvilinear in two directions, the grinder is required to be of a bulbous form and of the suitable diameter for the required curvatures, and the grinding and polishing tools must all be turned to the same diameter.

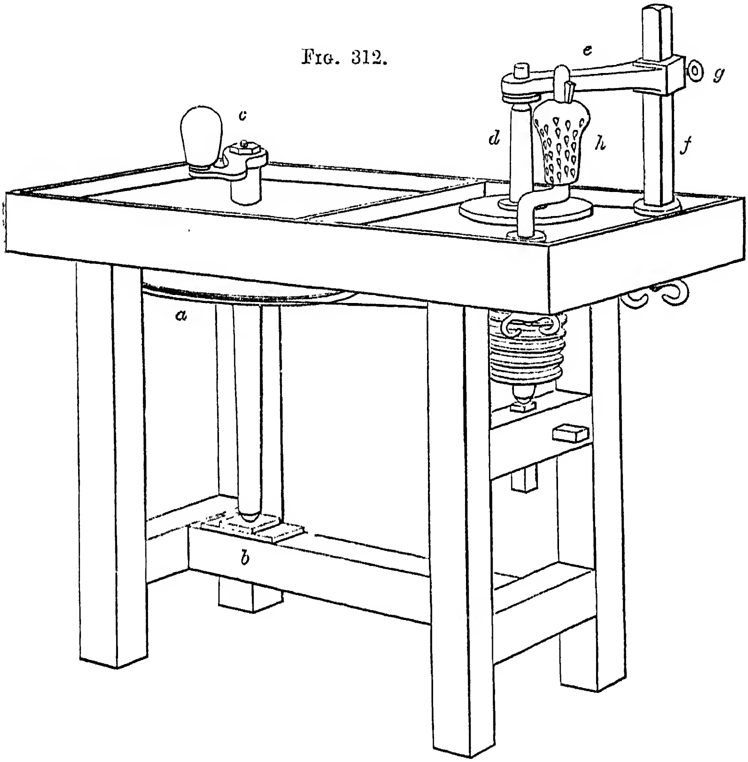
In Germany and other parts of the Continent, where large quantities of common lapidary works, such as brooches, knife and seal handles, are executed, water power is generally employed for driving the mills, which for these works are then frequently mounted upon horizontal spindles, and the edges of the mills are then principally used. The cutting of diamonds has been slightly noticed in Vol. I. page 176; as there mentioned, the facets are cut by cementing two diamonds upon the ends of two sticks, and rubbing them together. The facets are afterwards polished upon an iron skive or mill, charged with diamond powder; considerable pressure is exerted upon the stone, and where great quantities of diamonds are cut and polished, steam-power is generally employed, as at Messrs. Ford's at Clerkenwell, where very numerous polishing mills are all driven and at a considerable velocity from one shaft.

The stones worked in this country by lapidaries are generally small, and but little pressure has to be exerted upon them, the power of an assistant is therefore not required; but the lapidary usually gives motion to the wheel with his left hand, while the stone is applied to the mill with his right. The details of the apparatus sometimes vary in unimportant particulars, but fig. 312 may be considered to represent the most general arrangement.

The lapidary's bench consists of a stout plank, about 3 feet 6 inches long, and 1 foot 9 inches wide, supported upon a frame about 2 feet 6 inches high; the top is divided into two

unequal compartments, and the whole is surrounded by a rim of about 2 inches above the face of the bench, intended to catch the waste emery and water thrown off by the centrifugal force. The compartment to the left hand is about 2 feet long, and has a central hole fitted with a collar, through which

Fig. 312.



passes the vertical spindle of the driving wheel *a*, the lower end of the spindle is conical, and fits into a corresponding center *b*, fixed in the longitudinal rail of the frame. The driving wheel, about 18 inches diameter, is fitted on the spindle between flanges, and works just beneath the under surface of the bench top, which nearly conceals it, and a horizontal handle *c*, of about 6 inches radius, is fitted on the upper end of the spindle. The distance between the spindle of the driving wheel and that of the lap or mill, should not exceed about 1 foot 9 inches, in order that the arms may not be incon-

veniently extended when the hands are respectively applied to the wheel and mill.

The right hand compartment of the bench is about 16 inches wide, and through a hole in the center passes the spindle *d*, that carries the mill; this latter is usually about 8 or 9 inches diameter, and revolves about 1 inch above the surface of the bench. The spindle is about 18 inches long, and the mill is held between a flange and screwed nut, about 12 inches from the lower end, which is made conical, and received in a corresponding center capable of adjustment for height, in order to compensate for irregularities in the lengths of the spindles, and also to allow of the mill being more or less elevated above the face of the bench, as the edge or side of the mill may be employed at the time. In the bench represented in the figure, this center consists of a square wooden rod, usually of lignum-vitæ, passing through a mortise in the transverse rail of the frame, and retained at any desired height by a side wedge; but frequently the center is supported upon the middle of a transverse bar moving at the one end on a pivot in the back upright of the frame, and supported in the front by a wedge. The upper end of the spindle is also conical, and works in a wooden center, which is screwed into a hole near the extremity of a horizontal iron arm *e*, that slides upon a perpendicular bar *f*, fixed behind the mill; the height of the horizontal bar is adjusted to suit the height of the spindle, and is retained in the proper position by the binding screw *g*. The pulley, about four inches diameter, is fixed on the spindle to work just below the bench top, the hole through which is sufficiently large to allow the pulley to be passed through, either in exchanging the mills, or when they are required to be elevated.

The support shown at *h*, placed a little to the right and in advance of the lap, is called a *gim peg* or *germ peg;* it is about 8 inches high, and made of a round rod of iron bent into a crank form, and fitted with a flange that bears upon the surface of the bench; the lower end of the rod passes through a hole or mortise in the bench and is fixed by a wing nut beneath, in order to allow of the gim peg being twisted round to different positions, according to the distance it is required to be placed from the mill. The gim peg serves as a support for the wrist

or arm of the workman in grinding the edges of small stones, but its principal use is to serve as a guide for the vertical angle in cutting facets; for this purpose a wooden socket of the bulbous form shown in the figure, is slipped over the upper part of the rod, and retained in its position by a wedge driven in between the iron stem and its central aperture. Several series of holes, or notches, one above the other, are arranged around the sides of the socket, and serve to determine the inclination of the stick upon which the stones are cemented, as will be hereafter explained.

In producing a plane surface upon an irregular piece of stone, as in the case of smoothing a mineralogical specimen, if the natural surface be so nearly flat that but little has to be removed, the stone may be at once applied to the flat surface of the roughing mill; and if the stone be soft, such as a piece of potstone, the flat surface will be quickly attained; but if the natural surface be irregular and the stone be hard, such as a piece of bloodstone or even an ordinary pebble, the reduction of the stone to a flat surface by grinding would be very tedious if much of the material had to be removed. Splitting or cleavage is seldom resorted to, as few of the stones wrought by the lapidary have a sufficiently lamellar structure to allow of nearly plane surfaces being thus produced, and the surfaces would be also liable to interferences from flaws or veins in the stone. In the majority of cases, therefore, even in polishing mineralogical specimens, the level surface is produced by cutting off a thin slice of the stone with the slitting-mill or slicer, which is a revolving disc of thin sheet iron, charged on the edge with diamond powder, and used as a circular saw for dividing all stones inferior in hardness to the diamond.

Notwithstanding the apparent expense of the diamond powder it is very generally employed and is used for cutting nearly every Turkey oilstone that is sold; and although for this and some of the softer stones, emery, or in some cases even sand might be successfully employed, the diamond powder is almost exclusively used as it is found to be the most economical when the time occupied in cutting is taken into account. The diamond powder cuts more rapidly than emery, and is very much more enduring; it also admits of being employed with very thin plates, and consequently the progress

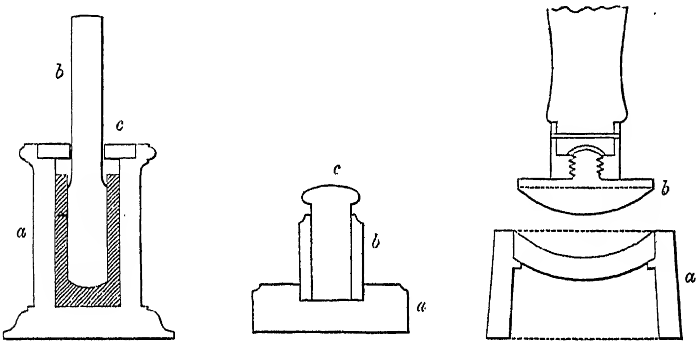
is also more expeditious on this account, and comparatively only a small thickness of material is wasted in the cutting. This is sometimes an important object with valuable stones, and the slicer is then made of small diameter, in order that it may be as thin as possible and still retain the required degree of stiffness.

The slicer is made of a disc of sheet iron, usually about eight or nine inches diameter, and two hundredths of an inch in thickness; and it is necessary that its edge should run exactly in one plane; it is therefore planished or hammered in the manner explained in vol. i., pp. 414 to 422. But if so thin a plate were made perfectly flat, like a circular saw, it would be very feeble sideways and would be readily distorted by the resistance of the work and, therefore, to give greater rigidity, the slicer is hammered into a slightly arched or dished form, the concavity being about one-sixth of an inch in the entire diameter. This trifling concavity materially increases its stiffness, and does not interfere with its use for cutting straight sections; as when the slicer is properly hammered and turned true, the extreme edge runs exactly in one plane for the commencement of the cut, and when the slicer has penetrated a small depth, the trifling curvature of the plate gives way and it is flattened by the groove it has itself cut and in which it is compelled to run. The slicer is further stiffened by being firmly clamped, like a circular saw, between two flanges on its spindle, which is made of such a length that the edge of the disc may be about 3 inches above the level of the bench, in order to allow room for the hand, and also for the thickness of large stones.

The preparation of the diamond powder for charging the slicer has been already described under the head DIAMOND, Article 2; but it may be added that the usual criterion for the fineness of the diamond powder used by lapidaries, is that the particles should be so small that no sparkling is perceptible when the diamond powder is exposed to the light. Slight differences are made in the forms of mortars for crushing diamonds, but that represented in fig. 313 is the more generally preferred. The mortar *a*, has a deep cylindrical hole terminating at the bottom in a spherical cavity of hardened steel, embracing from about one-third to one-sixth of a circle,

into which the pestle *b*, is accurately fitted by grinding. The long cylindrical fitting serves as a guide for keeping the pestle upright, and also prevents any of the valuable particles from

FIGS. 313. 314. 315.



flying about when the pestle is struck with the hammer; the cover *c*, is also added for the latter purpose. In some mortars for crushing diamonds, the bottom of the cavity is made flat, and the pestle is then made square at the end, as shown in fig. 314, in which *a* represents the base of the mortar, *b*, a short cylindrical tube fitted into a shallow cavity in the base, and *c*, the pestle, which is fitted within the tube. The first form of mortar is that usually employed by working lapidaries. The top of the pestle is struck with a hammer.

Sometimes, when the diamond has not been crushed sufficiently fine in the mortar, the lapidaries subsequently grind the powder; for this purpose they commonly mix it with a little olive oil or the oil of brick, and spread it upon a flat piece of iron, generally an old laundry iron, and any small piece of iron is used as a muller. The mortar represented in fig. 315 is, however, greatly preferable for grinding the diamond powder. The base *a* of the mortar has a spherical cavity, of hardened steel and about two inches radius, fitted by the pestle *b*, which is also made of hardened steel and fixed in a wooden handle. The diamond powder is placed in the center of the cavity, a few drops of oil are added, and it is then ground as fine as required by rubbing the pestle within the mortar with moderate pressure.

In applying the diamond powder to a new slicer, or as it is called *seasoning the slicer*, the latter is mounted in the machine, and the edge is turned quite true and smooth with a graver supported upon the rest *h*, fig. 312; in some cases it is afterwards smoothed with a fine file, as it is of importance that the edge of the slicer should be quite true and free from even minute notches, or otherwise the irregularities would be liable to catch the stone and throw it out of the hand, or if the stone were firmly held, the slicer would become distorted.

A small quantity of diamond powder mixed with the oil of brick, is then taken out of the cup with a little piece of stick, or a better practice is to employ a piece of an ordinary quill about 1 inch long, prepared by splitting the barrel of a quill lengthways into three or four pieces, and rounding the ends. The quill is dipped in the cup, and a little of the diamond powder, or rather paste, is taken on the concave side of the quill, which is then held vertically against the edge of the slicer, so that the curvature of the latter may nearly agree with that of the quill; the quill is then held steady while the slicer is moved slowly round, in order to distribute the diamond uniformly on the extreme edge of the disc. To fix the particles therein, a smooth piece of any hard stone, such as agate or flint, from half an inch to an inch wide, is then immediately applied with gentle pressure against the edge. In order that both hands may be at liberty for charging the slicer, the wheel is sometimes turned by an assistant, and the lapidary supplies the diamond powder with one hand while he holds the charging stone to the edge with the other. As soon as the diamond begins to cut the stone, the latter is shifted to another position, as, if the slicer were permitted to cut a groove in the charging stone, the diamond powder would become fixed in the sides of the slicer, which must be avoided; and so soon as the small quantity of diamond resting on the edge of the slicer has been pressed into it, the margin of the disc is carefully wiped on both sides with the forefinger, in order to remove any small portions of the diamond that may have become accidentally lodged on the sides, and these particles are pushed to the edge of the slicer, and pressed in with the charging stone. When the whole of the diamond powder has been pressed into the extreme edge, a second quantity is

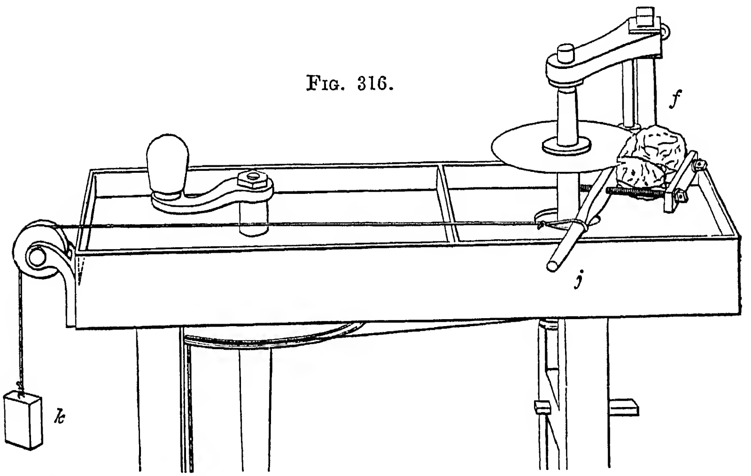
applied in the same manner, and this is generally sufficient for charging or *seasoning* a new slicer. After the edge of the slicer has been once fairly charged with the diamond powder, a single application is generally sufficient for restoring the cutting edge, and under the hands of the practical lapidary, a single seasoning will endure several hours' work.

The stone to be sliced is first washed clean and dried, the line of the intended section may then be marked in ink as a guide, and the slicer is plentifully lubricated with the oil of brick, or with ordinary paraffine. Oil of brick is a thin oil prepared as described in the catalogue, employed on account of its limpidity, and as not being liable to become thickened by exposure to the atmosphere. The common paraffine oil of commerce is found to answer equally well for all lubrication in cutting, and as its cost bears no comparison to that of brick oil, it is now more generally employed by both the lapidary and seal engraver. Stones of small or moderate size are held in the hand, while the arm is rested upon the edge of the bench to steady it. The stone is then lightly pressed against the edge of the slicer, which is driven with only moderate velocity, or the friction would be liable to heat the stone and perhaps cause it to crack. Care is taken in the commencement of the cut to present a tolerably smooth surface to the slicer, as if a sharp corner were first advanced, it would be liable to scrape the diamond off the edge; and the diamond may also be torn off the edge if a smooth stone be pressed too forcibly against the slicer with the view of expediting the process. During the slitting the slicer is kept plentifully supplied with the oil of brick or paraffine, and the stone is held steadily and cautiously managed to keep the cut in a straight line, as from the concave form of the slicer it is rather liable to cut upwards. The principal attention is however required at the first commencement, and if this be correctly performed, the groove will serve in a great measure as a guide for the completion of the cut.

When the stone to be sliced is too large and heavy to be conveniently held in the hand, it is mounted on the *crane*, as shown in fig. 316. The crane consists of an upright rod, mounted between centers, just in front of the perpendicular bar *f*, and upon this slides vertically a horizontal arm *j*, about

20 inches long, provided with a binding screw, by which it may be fixed to the rod at any height. The stone is fixed to the middle of the arm and opposite the slicer, by means of a clamping piece and two binding screws, as seen in the figure, and the whole is drawn forward by a weight *k*, attached to a line leading from the extremity of the horizontal arm, over a

FIG. 316.



pulley fixed to the end of the bench. The stone to be sliced is carefully clamped so that the line of the intended division is exactly horizontal, and the precise height is adjusted by sliding the horizontal arm upon the vertical rod until the line of division just meets the edge of the slicer. The weight then suffices to keep the stone continually pressing against the edge of the slicer, and the operator has merely to keep the latter in motion, and supply the lubricant.

For cutting parallel slices, it is only requisite between every cut, to shift the horizontal arm upwards upon the vertical rod. This simple contrivance entirely removes all difficulty in holding the stone, but is very seldom resorted to by practical lapidaries except for large stones. A modification of this instrument to adapt it to the use of amateurs for cutting small stones will be adverted to.

To remove the marks made by the slitting the flat surfaces of the stones are ground upon the roughing mill, or lead lap,

supplied with coarse emery and water, by means of a brush. If large and thick, they are held directly in the fingers, but more generally the stones are too thin to be thus held, and it then becomes necessary to cement them to a wooden stick to serve as a handle. Large thin stones would also be liable to be broken in working if left unsupported, such stones are therefore cemented upon a handle made as a flat disc of wood nearly as large in diameter as the width of the stone, and having a central stem 4 or 5 inches long, and about half an inch diameter.

The cement is made of rosin tempered with bees-wax and a little tallow, and hardened with red ochre, or Spanish brown and whiting; the smaller and harder the stones, the harder the cement is made by an increased quantity of the powders. For sapphires and other hard gems, a little shell-lac is sometimes added to the cement to increase its tenacity. To cement the stone upon the stick, the wooden disc is first warmed over a lamp or candle, the cement is then heated and evenly applied to the surface and edges of the disc, the layer of cement being made sufficiently thick to allow of the stone being fairly embedded, and it is then worked with the fingers nearly to the form of the stone, which is next warmed just sufficiently to cause the cement to adhere, without making it so hot as to be liable to burn the fingers; the surface of the cement is then melted over the lamp, and the warm stone is immediately pressed upon it. Care is taken to place the stone quite central with the stick, which should also be exactly at right angles with the flat surface of the stone. The cement around the edges of the disc is then worked with the fingers into the angle around the stone, to support it uniformly near the edges.

In charging the lap with emery, a small brush dipped in water is generally applied to the lap to moisten it, and the dry emery is then sprinkled over its surface and rubbed in with a flat piece of emery stone or a piece of sheet iron; but some lapidaries prefer to dip the moistened brush in dry emery, and then apply it to the lap. In whichsoever way the emery be applied, it is desirable that as much emery should be supplied at the commencement of the roughing as it is judged will suffice for the removal of the marks made by the slicer, and should more be required as the work progresses,

the coarser particles remaining of the emery first supplied are partially crushed, either with a smooth lump of emery stone, or with a piece of soft sheet iron about 1 inch wide and 8 inches long, and the work is completed with a finer size of emery, so as gradually to reduce the coarseness of the grinding powder as the flat surface is approached. As mentioned under the head ALABASTER, Article 3, many lapidaries employ the same lead mill both for roughing and smoothing the surface of the stones; some however employ two benches for these purposes, so that the work may be taken from the roughing mill to the smoothing mill without the loss of time incurred in crushing the coarser emery quite fine, but when one bench only is used for the roughing and smoothing, the same lap is made to serve both purposes. For large stones the roughing is generally commenced with grinding emery, and finished with flour emery; but for small stones superfine grinding emery is sufficiently coarse for the commencement, and fine flour emery is used for the smoothing.

In applying the stone to the mill, it is placed flat on the surface, and firmly pressed with the ends of the fingers and thumb applied on the back of the wooden disc, the upright stem passing between the fore and middle fingers. If the stone be large, it may, with advantage, at the commencement, be rubbed upon the flat face of the revolving mill with small circular strokes and at the same time the stone may be slowly twisted round with the fingers, in order to expose it equally to the action of the mill. If the stone be small it must be held quite steadily throughout the process, but in order to wear the lap uniformly the stone is placed in a different position every time that it is rested on the mill.

The velocity of the mill employed in grinding should be only moderate, so as just to avoid throwing off much of the grinding powder by centrifugal force; the progress of the work may be expedited by using a higher velocity, but the emery and water are then thrown off so abundantly as to be very objectionable and the condition of the work can be less delicately felt. The stone should also be pressed upon the mill with only moderate force, as great pressure is liable to cause it to push away the loose particles of grinding powder and also to wear the mill irregularly, whereas moderate

pressure allows the loose particles of emery to roll over between the mill and stone and the work then progresses more rapidly and the mill is less injured. The stone having been made as smooth as practicable with the emery, the polishing is proceeded with in the same manner, upon a mill of appropriate material, generally pewter, hacked, or jarred, as explained under the head CARNELIAN, and supplied with rotten-stone and water. This completes the one side of the stone; it is then detached by heat from the cement stick and the same routine is followed with the second side.

If it be required to work the stone a definite shape, such as an oval, the edge is ground to the oval form before the sides are flattened. For this purpose a corresponding oval is cut out of card to the exact dimensions, and laid upon the stone; the oval is then marked with ink upon the stone, which is brought very nearly to the shape by means of *nippers*, or flat pliers of soft iron, similar to those described for rounding discs of glass preparatory to grinding them into lenses, the nippers are firmly compressed upon the stone, and then twisted sideways to break off small particles. The hardest stones, such as sapphires, will yield to the action of the nippers, although they are scarcely ever used upon valuable gems; but if the stones are smooth and rounded like the natural surface of a pebble, the nippers will slide off, and therefore such stones are first slightly roughened to give a hold to the nippers. The stone having been nipped of the required shape and nearly to the size, it is cemented upon a stick, the edge being left exposed, and this is then ground square by holding the stick horizontally and continually twisting it round between the fingers to avoid grinding flat places; when the stone has been thus figured to the required shape, the flat face is ground and polished.

If the stone be required to have a bevelled edge or chamfer around the face, it is first nipped to the form, then fixed on the cement stick, with the side outwards that is to form the back of the stone; the edge is ground square and the back flattened and polished if necessary. The stone is then re-cemented upon the stick with the face side outwards; the face is flattened, and the bevelled edge is then ground by holding the stick at an angle, and continually twisting the stone round

to grind the chamfer uniformly. The thickness of the narrow square edge left on the stone, serves as a sufficient guide for practised lapidaries to ensure the uniformity of the bevel, but the amateur will probably find it desirable to mark a line on the edge, and also on the face of the stone, to show how far the chamfer should extend.

If the stone is to have a rounded edge, it is first prepared with a bevelled edge exactly as above, and the angle is removed by a rocking motion of the stone upon the flat mill. For this purpose the stick is held underhand, being grasped between the fingers as near to the bottom as admissible, and the stick is continually traversed from nearly the perpendicular position to the angle, at which the chamfer was ground. The wrist or elbow being the center of motion according to the curvature required, and at the same time the stick is twisted round in the fingers in order to round the edge uniformly.

If the stone is to be considerably rounded over the entire face, the preparatory step of grinding the face flat may be omitted, as the stone will be left sufficiently level by the slicer, and the principal bulk of the material is removed by the chamfer, which serves as the basis or guide for keeping the rounding uniform, assisted during the principal portion of the work by the central part of the stone, not reached by the rounding until near the conclusion of the rough grinding.

If the stone to be rounded on the face be circular, it is rolled upon the flat mill with circular strokes; between every few strokes it is shifted to another part of the mill, and the stick is continually twisted round in the fingers. If the stone be of a short elliptical shape, it is treated in the same manner, except that it is traversed in an elliptical path. In the case of very long ellipses, the two sides of the ellipsis are first ground separately with a rocking motion, and the stick is slightly twisted in the fingers between every few strokes. The ends of the ellipsis are rounded in the same manner, and, lastly, it is smoothed with long, semi-elliptical strokes. The principal guide for the degree of rolling is obtained from an inspection of the progress, but the sense of feeling is also greatly trusted to by working lapidaries. Stones that are flat on the back, and much rounded on the front, are called *tallow tops*, from their resemblance to a drop of tallow.

Stones that are rounded to a cylindrical or conical form, such as a drop for an earring, are cemented sideways upon a stick, and the one-half ground to the semi-circular section; they are then detached from the stick, and cemented with the other side outwards, and this is similarly wrought. Some care is required to grind the two semi-circular sections exactly opposite to each other; and when this has been done as nearly as possible, the stone is successively cemented in two other positions at right angles to the two first, in order to expose the junctures of the two curved surfaces first produced, which are then corrected.

Stones that are to be ground into spheres for beads or the heads of pins, are, in like manner, required to be cemented in at least four positions before they can be brought sufficiently near to the required form. The method of grinding perfectly true spheres has been already explained in a foregoing chapter, but this amount of accuracy is not required for lapidary purposes, as, generally, the form is only required to be sufficiently correct to satisfy the eye. With the view of expediting the process of grinding stones that are much rounded, and also to preserve the lap used for flat surfaces, one lap is generally set aside to be used only for rounded works, and, from constant use, the face of this lap becomes worn into numerous hollows, of different sizes, some of which are generally found to nearly fit the curve of the stone being ground. This materially lessens the difficulty of producing spherical surfaces, and the edge of the same lap is generally rounded off to serve for concave works.

In grinding a pebble to the shape of a heart with rounded sides, the pebble, if much thicker than the intended heart, is first cut to the suitable thickness with the slicer; it is then marked from a card pattern, and nipped nearly to the form and size. The edges are then squared, the square angle of the lap being employed for making the indentation at the top of the heart. So far, the stone is generally held in the fingers; and when the outline has been thus produced, it is cemented on a stick, the edges are chamfered all round, and the stone is rough-ground to the rounded form, smoothed, and polished; the second side is then treated in the same manner. Small stones cut in a form of a shield, as for a signet ring, are,

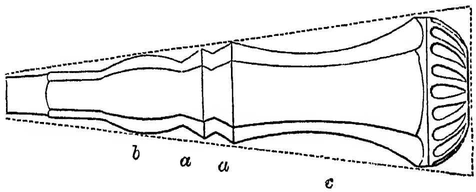
in the same manner, first wrought to the outline of the shield while held in the fingers, although these stones are often not more than one quarter of an inch in height. In holding such small stones, some care is required to avoid bringing the fingers in contact with the lap, which would be likely to grind through the skin even before the operator was fairly aware that they touched the lap, the grinding action being almost insensible until the outer coat of the skin is worn through.

Stones that are semi-transparent, such as garnets, are frequently left round on the face, or cut *en cabochon;* but such stones, if left of the full thickness, would be too opaque to display much brilliancy, and, therefore, with the view of increasing the transparency, garnets cut en cabochon, and called carbuncles, are generally hollowed on the under side to make them thinner. The hollow on the under side is ground upon small spherical grinders of lead, called balls, made of various thicknesses and diameters, but mostly about the size of bullets. The balls are mounted upon a small conical spindle, that is fitted to the ordinary lapidary's bench; the holes through the balls are also made slightly conical, so that they may be retained upon the spindle by the plain fitting, and allow of being readily detached for the substitution of other balls of different sizes. Similar balls made of pewter, are employed for polishing; and it is also necessary that the grinding and polishing ball should be, as nearly as possible, of the same size.

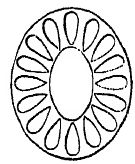
For cutting small mouldings, or hollows, in the edges or sides of stones, the lapidary employs little lead mills, not exceeding about three inches diameter; they are generally held by a plain fitting upon the same spindle that carries the ordinary mills, which is made somewhat conical for the purpose. The edges of these mills are principally used, and they are made of various shapes and thicknesses, but mostly with rounded or angular edges in order to penetrate the cavities of hollow mouldings, and the rounded parts are chiefly produced by rolling the work over the edges. The small diameter of these mills allows of delicate works being better seen and, from the velocity being less at the edge of the mill, the position and progress of the work is also more readily appreciated by the sense of feeling.

In cutting a seal handle, with an octagonal section, and a rounded top, such as fig. 317, the stone is first sliced into the pyramidal form indicated by the dotted lines; the sides are then flattened and the angles removed upon the ordinary roughing mill to bring the stone to the octagonal section, and the top is rounded. The indentations at *a a* are then cut

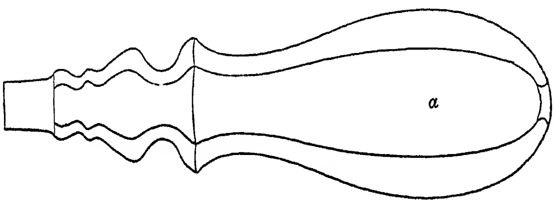
Figs. 317.



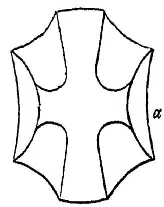
318.



319.



320.



upon the angle of a mill having a square edge. The curved portion at *b* is cut upon a mill with a slightly rounded edge which also serves for removing the principal portion of the material from the large hollows at *c*; and these are afterwards corrected either by applying the stone transversely upon a lap with a rounded edge, turned to the required curvature, or by applying the stone longitudinally upon a square edged mill, of about two inches diameter, the curvature of which would correspond with the hollows in the figure. The small flutes in the rounded top are cut with a mill of small diameter having a narrow rounded edge.

In cutting the handle, figs. 319 and 320, the stone is roughed out to the general contour upon mills with rounded edges of appropriate thicknesses. The stone is first wrought of an elliptical section throughout, by continually twisting it round in the fingers. The two longest sides are then flattened by holding the stone firmly in the fingers, and traversing it backwards and forwards a small distance upon the edge of the mill; the four angles are removed in the same manner, and

the two narrow ends of the irregular octagon are formed by portions of the original ellipsis, the curvature being scarcely perceptible in the lower part of the handle. The two large flutes, *a*, are cut by traversing the stone over a mill of about two inches diameter with a rounded edge, and the four small flutes are cut upon a similar mill of smaller diameter. In all these cases, no guide whatever is employed for producing the form, the perfection of which depends entirely upon the figure of the edge of the mill and the dexterity of the workman. Sharp internal angles are not often attempted, as it is difficult to maintain the sharp angle of the grinder.

The minute cutting on the surfaces of small works, such as coral drops for ear-rings and similar objects, is performed by another class of artizans, who mount small angular, flat, or rounded grinders upon horizontal spindles in the ordinary lathe, and apply the work beneath the grinders in much the same manner as the glass-cutters ; indeed, coral cutting may be considered to form a link between glass-cutting and seal engraving, described respectively Chapters IX. and XI.

For perforating very small holes through beads and similar objects, the lapidary employs as a drill a small steel or iron wire, such as fig. 67, page 178, Vol. I. The wire is mounted in a chuck to revolve horizontally upon an ordinary lathe mandrel, and is charged upon the end face with diamond powder in the same manner as the slicer. For holes more than about the twentieth of an inch diameter, tubular drills are used, such as fig. 71, made of thin sheet iron, bent around a small central wire and turned or filed true. These drills remove a small solid core, which breaks when the tube has penetrated some little distance, and the core is pushed out of the tube by passing a fine needle through a hole in the side.

Larger tubes are employed in the same manner for cutting out the circular holes sometimes made in brooches for the insertion of another stone, or of a locket. If the hole is required to be oval, two circular holes of suitable size are made to constitute the two ends of the oval, and the little angular pieces left between the two circles are removed with a small conical grinder. Small tubes are soldered upon the metal wires, but those exceeding about half an inch in diameter are, by the lapidary, generally attached by cement in a

wooden chuck. These annular drills are sometimes made as large as from one to two inches diameter, and thus the lapidary's tubular drills are carried up to the size of the smallest circular cutters or grinders used for similar purposes in marble. It is generally considered that all these tubular drills used by the lapidary, perforate more rapidly and are less liable to clog or bind in the hole when lubricated with paraffine than with oil of brick.

SECTION II.—CUTTING FACETS.

The surfaces of gems, pastes, and most other substances worked by the lapidary, are, as is well known, cut into facets to improve their brilliancy, by multiplying the number of reflecting surfaces in order that the play of light may be proportionally increased. Facets are principally cut upon transparent and semi-transparent stones, but sometimes also upon opaque stones, such as carnelian; and speaking generally, it may be said that the greater the natural brilliancy of the stone, the fewer facets are necessary to produce the required play of light; and with valuable gems it is always desirable to produce the brilliancy with as few facets as possible, in order to avoid confusion in the rays of light.

Opaque stones are cut on the face only, and the stone is in general thin, and flat on the back; but transparent stones are, if possible, left thick, and so cut as to make the back, or lower part of the stone that is enclosed in the setting, of about double the thickness of the front or face that is exposed. The back of the stone is cut into facets or squares that exactly correspond in plan with the position of the principal facets on the front of the stone; and the angles which the squares at the back make with the axis of the stone, are required to be such, that all the light reflected from their surfaces may fall within the central flat surface on the front of the stone, called the *table*. The facets are arranged upon the stones in a great variety of methods, but they may nearly all be considered as modifications of three principal varieties, namely, the *trap cut*, the *brilliant cut*, and the *rose cut*, one of the two latter forms being always employed for diamonds.

The trap cut, or trapping, as it is called by lapidaries, consists of parallel planes nearly rectangular, arranged round

the contour of the stone, as shown in figs. 322 to 327. This cut is always used for emeralds, and sometimes also for the fronts of other gems, but it is principally employed for the backs of stones, the fronts of which are cut in one of the modifications of the brilliant cut.

The brilliant cut consists of lozenge-shaped facets alternated with triangles, as shown in figs. 328 to 329, and is used for the fronts of most transparent stones that are sufficiently thick to allow of being cut into facets on both the front and back. The different modifications of this form of facetting are known as the half brilliant, or single cut; the full brilliant; the split brilliant, or trap brilliant; and the double brilliant, or Lisbon cut; according to the arrangement of the principal facets.

The rose cut consists of triangular facets arranged upon and around a central hexagon, as in figs. 340 to 344. This cut is employed upon such stones as are thin and large on the surface, or, as it is called, much *spread*, as the rose cut is applied only on the front of the stone and the back is left flat. The rose cut is considered to give the greatest lustre that can be obtained from cutting the front only, as the surface is entirely covered with facets, and on this account the rose cut is sometimes applied to opaque stones, but its principal application is to the diamond or to other colourless gems employed as fictitious diamonds, such as the jargoon.

In all cases of cutting valuable gems, the principal object of the lapidary is to fashion the stone so as to produce as much display as can be attained without materially reducing the size of the gem, and this circumstance in great measure determines the manner in which it is cut. This is especially the case with the diamond, which is always found in the shape of an octahedron more or less perfect in form; and unless the diamond has defects, it is always cut as a brilliant with an octagonal base, that being the largest regular figure that can be inscribed within the octahedron. Diamonds that have defects are split by cleavage, and the pieces are cut into rose diamonds, which form is also adopted for those whole diamonds that are too thin to be cut into brilliants. Other valuable gems are in like manner cut into the largest regular forms they will respectively produce.

With less valuable stones and pastes, the reduction of the

material is of less importance and the form of cutting is rather a matter of choice than otherwise; but in order that they may the more nearly resemble valuable gems, they are usually cut into corresponding forms; this is especially the case with pastes, which are cut on the front in exactly the same manner as the gems they are intended to represent, and the cutting at the back is only modified, so as to cause the play of light to assimilate to that of the gems themselves.

In all cases of cutting gems or pastes into facets, the general contour of the stone is first produced by roughly grinding it into form, much the same as for a rounded stone. Generally the first step is to grind a flat face upon the stone, in order to judge of its quality and ascertain whether it contains any imperfections, and, if so, the cutting is modified accordingly. If the stone proves to be tolerably perfect, and it is to be cut into facets upon both the front and back, the flat surface first cut is made to constitute the table of the stone, and the edges are corrected to bring it to a regular figure, generally a circle or ellipsis, but sometimes a square, or oblong, with the corners rounded off, according to the shape that can be produced with the least waste of material. The edge thus ground forms the *girdle*, or extreme margin of the stone by which it is retained in the setting. The part between the girdle and table, called the top of the stone, is then rounded or bevelled off to about the extent that the facets are desired to extend. The back of the stone is afterwards rounded in the same manner to the general shape, leaving a small central plane called the *cullet*, or *cullasse*.

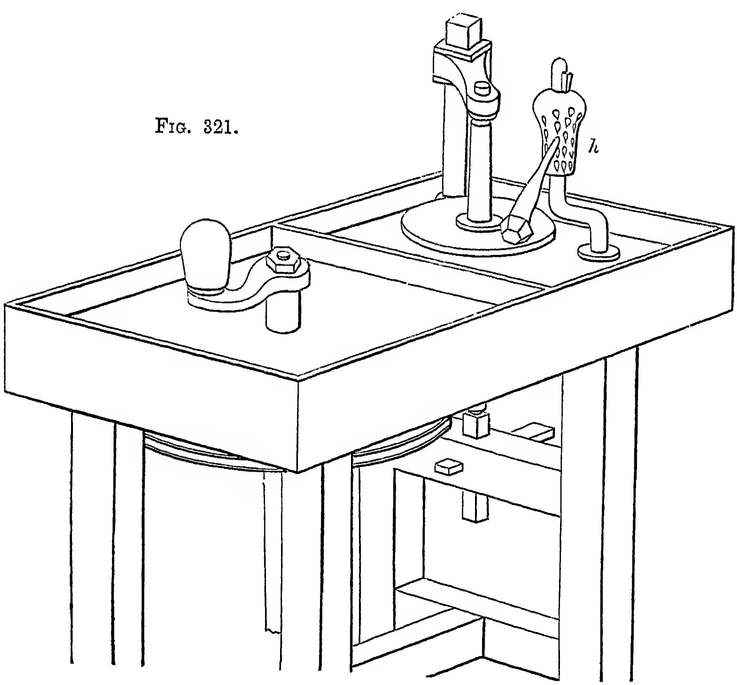
If the stone is to be cut into facets on the front only, the flat face first cut is mostly made to constitute the back of the stone, the edges are corrected for the girdle, and the front is prepared by cutting, first, a flat face for the table, and afterwards rounding or bevelling the top. So far the stones are prepared in the same manner to the general shape, whatsoever form of facetting is to be adopted.

The square cut, or trap cut, is the most simple form of cutting facets, and also serves as the foundation of the facets of the brilliant cut. The method of producing the trap cut will be therefore first described, and this will be followed by some observations on the brilliant cut. In order to avoid

confusion, it will be more convenient to limit the majority of the examples to elliptical stones cut with eight principal planes or facets, one on each of the sides of an irregular octagon. Stones are frequently cut with as many as twelve or fourteen sides, but the general method is exactly the same, whatever may be the number of sides.

Fig. 322 represents in plan, and fig. 323 in side elevation, a stone cut on the face only with a single row or *height* of eight planes or squares connecting the central table with the girdle. In cutting this form, the stone is cemented upon a stick with the side to constitute the back outwards; this is then ground flat, the edge cut into shape for the girdle, and the back polished; the stone is then re-cemented upon the stick with the front outwards. The stick should be a little smaller in diameter at the end than the size of the stone, which requires to be placed exactly centrally upon it and with the flattened back as nearly as possible at right angles to the axis of the stick, in order that the table may be cut parallel with the back,

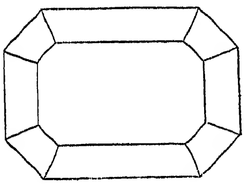
FIG. 321.



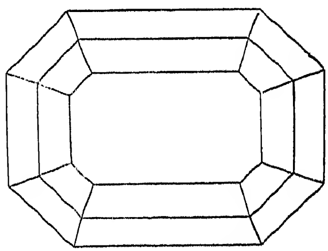
and also that the squares on the top may be all cut at the same angle.

The cutting on the front of the stone is commenced by grinding the flat table; a uniform bevel is then cut around the top. The bevel is made of about the width of the desired squares, and is called a *water basil*, from its running uninterruptedly around the stone. So far the process is exactly the same as for cutting an elliptical stone with a bevelled edge. The eight squares, or facets, are then cut upon the bevelled edge. For this purpose the stone is applied to the mill as shown in fig. 321, the gim peg, *h*, being adjusted for position, until upon trial it is found that, on placing the stone fairly upon the lap or mill and inserting the upper end of the stick in one of the notches in the wooden socket, it is inclined at the same angle as that at which the water basil was ground. The gim peg is then fixed by the wing nut beneath the bench, and the wooden socket secured by the wedge; the mill is then put in revolution, and the stone is applied, first to cut the two facets on the longest sides opposite to each other, and then those at the two ends are cut as nearly square as practicable, under the guidance of the eye alone; lastly, the four squares

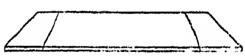
FIGS. 322.



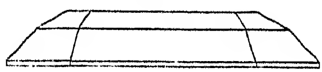
324.



323.



325.



at the corners are cut to bring the stone to the octagonal form.

The four planes first cut at right angles serve as the basis of the figure, and some care and practice are required to place them exactly square, but the process is less difficult than might be anticipated, as in cutting the first pair of opposite

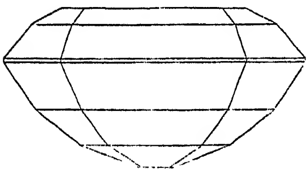
planes it may be readily perceived whether or not they are parallel, and should they not be correctly placed at the first attempt, the stick is slightly twisted in the hand for changing the position of the squares. But little pressure is exerted upon the stone, with the fingers applied above the stick and as near to the stone as convenient. The square position of the pair of planes at the two ends, may in like manner be estimated very nearly by a practised eye, and these foundation squares having been correctly placed, the position of the four squares at the corners is tolerably easy of attainment, and these squares are gradually enlarged until the desired figure is produced. In elliptical stones the corner squares are mostly smaller than the others, in order to avoid the reduction of the material. In cutting a stone with twelve squares on the same height, the four squares at right angles are first cut in the same manner, and the figure is completed by cutting two facets at each of the four angles, instead of one only as for the octagon. Stones with ten or fourteen facets on the one row are rather more difficult to cut by hand, as only the two opposite facets in the middle can be derived from the square figure.

Figs. 324 and 325 represent a thicker stone trapped in two heights, or cut with two rows of square facets, one above the other, and placed at different angles to the table of the stone. The row of squares adjoining the girdle is always left somewhat wider than that adjoining the table, partly with the view of compensating for the narrow portion enclosed in the setting. The stone is prepared in exactly the same manner as for a single height of trapping, except that two water basils of the desired widths of the squares, are cut upon the top of the stone. The row of squares near the girdle is first cut, the cement stick being inserted in the same hole in the gim peg for cutting every square in the same row. The row of squares adjoining the table is then cut in the same manner, except that the stick is inserted in a higher hole in the gim peg in order to place the squares at a greater angle; and some care is required to cut the upper row exactly opposite the lower.

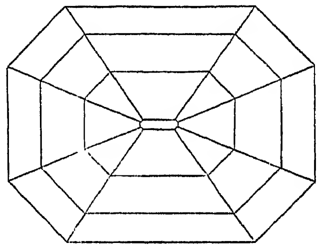
As previously mentioned, transparent stones that are of sufficient thickness, are generally cut both on the front and back. In this case about one-third of the entire thickness is

given to the front, and about two-thirds to the back, as shown in figs. 326 and 327, which represent the side elevation and back plan of a stone trapped in two heights or rows of squares on the front, like fig. 325, and three heights at the back, a style of cutting frequently adopted for small emeralds and other stones. Those of medium size have generally four heights on the back, and very large emeralds sometimes have

Figs. 326.



327.



three heights of trapping on the face, and from five to eight heights on the back; but with emeralds the trap cut is not often carried to the latter degree of elaboration, unless it be done with the view of keeping the gem as heavy as possible, as the greater the number of heights in the trapping, the more roundness can be given to the general contour of the back, and consequently greater weight to the stone; but if the convexity be too great, it detracts from the lustre of the gem.

In cutting a stone to the form of fig. 326, it is cemented on a stick, the flat surface of the table is first cut, and the edge is brought to the desired shape of the girdle. Two water basils are then cut around the top, in the same manner as for fig. 325, but the facets on the front are not cut until the back has been completed; for this purpose the stone is re-cemented upon the stick, and the back is rounded to the general form; a single water basil is then cut around the girdle, to determine the height of the first row of squares, and these squares are next cut, with the aid of the gim peg; the second row of squares are then cut in like manner, but without the preparatory step of cutting the water basil, as the first row of squares serves as a sufficient guide for keeping the squares in the second row uniform; the third row of squares is cut in the

same manner, the cement stick being shifted to a higher notch in the gim peg between every row; and, lastly, the stick is held vertically to cut the culasse.

The squares are then polished in the same order, the gim peg being carefully adjusted for height between every row, in order that the stick may be inclined at exactly the same angle as that employed for cutting the squares. As mentioned in the catalogue, a pewter mill supplied with rottenstone and water is employed for polishing stones of about the hardness of carnelian, and a copper mill is generally employed for harder gems. Some lapidaries, however, prefer a bell-metal mill for polishing hard gems, such as the sapphire, as the bell metal, being harder than the copper, the mill is less liable to be worn into ridges. The stone, when polished on the back, is detached from the stick, and re-cemented with the front outwards. The position of the stone requires to be very carefully adjusted to make it exactly central and square with the stick, or the front of the stone would be liable to be cut oblique to the back. When the stone has been properly adjusted, the squares are cut on the front of the stone exactly as for fig. 325. The surfaces of the table and squares are then polished, and the stone is detached from the stick by gently warming it over a candle. Lastly, the stone is washed with turpentine to remove any small particles of cement.

The brilliant cut, variously modified, is the form of facetting most generally adopted for the fronts of gems and pastes, and the backs of these stones are mostly trapped, or cut in squares. The principal varieties of the brilliant cut are represented in figs. 328 to 339, in which every stone is shown in three views, viz. the plan of the front of the stone, the side view, and the plan of the back. The dotted lines around the upper halves of the front views, are inserted to show more distinctly the manner in which the brilliant cut consisting of lozenge-shaped facets alternated with triangular facets, is derived from the square or trap cut by the removal of the angles indicated by the dotted lines. With the same view of rendering the diagrams more distinct, the outlines of nearly all the girdles are represented of the polygonal forms they would assume, if the facets adjoining the girdles were made strictly angular so as to terminate in straight lines upon the girdle.

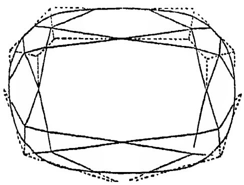
In the brilliant cut, however, the girdles are not generally shaped to the polygonal forms, but they are made as easy curves, nearly approaching the forms shown in the diagrams if the extreme angles are supposed to be removed; and in cutting the rows of facets adjoining the girdles, these angles are not quite developed. The rounded form of the girdle is adopted partially with the view of keeping the stone as large as possible, and avoiding the liability of the angles being chipped in cutting the facets, and partially because the rounded girdle is more convenient in setting the stone.

The size of the table, in proportion to that of the girdle, depends in great measure upon the thickness of the stone, compared with its width or *spread*, and the taste of the lapidary, no invariable rule being adopted; but the table is seldom made less than half, or more than two-thirds, the length of the girdle. The size of the culasse is very small, being only just sufficient to prevent the facets at the back of the stone from meeting in a point, and its width is seldom more than about the thirtieth of an inch, although in large and long stones it is sometimes as much as one quarter of an inch in length. The culasse has the effect of reflecting a small quantity of light into the table, that would otherwise be lost; but its principal purpose is to prevent the formation of a weak angle, that would be liable to be easily broken.

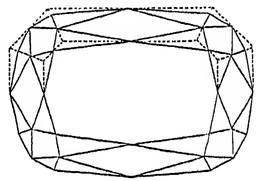
The half brilliant, figs. 328 to 330, is the most simple variety of the brilliant cut, and is very generally employed for those stones that are too small to admit of numerous facets being cut upon their surfaces. In cutting a stone to the form of the half brilliant the front is prepared exactly as for a single height of trapping, the first step being to cut the table; secondly, the girdle; and thirdly, the water basil. The stone is then inverted for cutting the back; in the figure this is shown as consisting of two rows of squares, or trapping, with eight triangular facets cut upon the angles of the eight squares adjoining the girdle; these triangular facets are called *under squares*, and are very generally employed upon stones that are trapped on the back, partly in order to diminish the size of the large squares and increase the number of facets, and partly to give the stone a more rounded figure, by removing the prominent angles that would be liable to interfere with the setting.

In cutting the back, the stone is first rounded to the general contour; secondly, the culasse is cut; thirdly, the water basil for the row of squares adjoining the girdle; fourthly, the eight principal squares are cut on this row; fifthly, the eight squares adjoining the culasse; and lastly, the eight under squares, and the polishing completes the back.

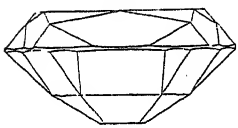
Figs. 328.



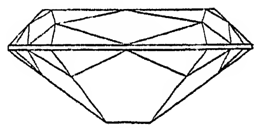
331.



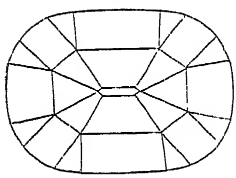
329.



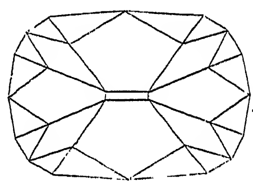
332.



330.



333.



The stone is again inverted upon the cement stick for cutting the facets on the front, and the table is first corrected, eight squares are then cut upon the water basil, exactly as for fig. 322, as represented by the dotted lines around the upper half of fig. 328; and the surfaces of the eight planes thus produced constitute the surfaces of the eight principal planes in the finished stone, as shown in the figure. These planes are called *foundation squares*, and are converted into the pentagonal shape shown in the figure, by cutting one row of eight triangular facets around the table, and another row of eight triangular facets around the girdle. The bases of all the upper row of facets around the table, extend from the center of the upper edge of one foundation square to the center of the upper edge of the adjoining square, and the apex touches the

point of the pentagon upon the line of intersection of the two squares; thus removing the entire angle indicated by the dotted lines in the figure, and altering the position of the original octagon constituting the table of the stone, at the same time that its size is reduced by the removal of its angles. These triangular facets are called *skill facets*, from the difficulty of placing them correctly.

The lower row of eight facets around the girdle is produced by cutting a triangular facet upon every one of the lower angles of the foundation squares, every lower facet is placed exactly opposite the corresponding skill facet, and is extended perpendicularly until it reaches the point of the skill facet; but, in the half brilliant the lower row of facets is not extended laterally to the middle of the foundation squares, as this would remove too great an angle, and diminish the size of the stone. The lower facets are therefore cut only so wide as can be ventured without interfering with the rounded form of the girdle. The dotted lines on the lower half of fig. 328 are inserted to show that the lozenge is the primary form of the foundation squares in all the varieties of the brilliant cut, and the pentagonal form of these squares in the half brilliant arises simply from the lower facets being only partially developed.

In all cases of facetting transparent stones, it is very important that the foundation squares on the front should be equal in number, and exactly opposite to the principal squares on the back, and also that the lower facets should be opposite to the under squares, or otherwise the play of light would appear confused and the brilliancy of the stone would be materially reduced. In order to place the squares opposite, it is quite necessary that both the front and back of the stone should be cut accurately with reference to the shape of the girdle, as the back of the stone requires to be entirely embedded in the cement at the time the front is cut; and the only guide employed by the lapidary for the correct position of the squares, is derived from the general shape of the girdle and the certainty that the back squares have been correctly placed.

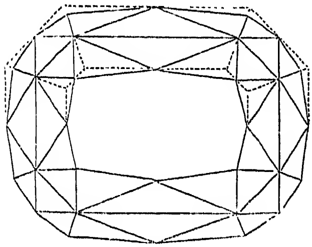
The full brilliant cut represented in figs. 331 to 333, may be received as the foundation from which the other varieties of the brilliant cut are derived, and is considered to be the most

perfect form of facetting for gems. It is therefore almost invariably employed for all diamonds that are sufficiently thick and perfect to admit of its application; but diamonds, from their crystallisation in the form of the octahedron, generally have a nearly regular octagon for the table and base, instead of the irregular octagon selected for illustration. Diamonds cut into this form are called *brilliants*; and the term brilliant cut, when used alone, is always understood to imply that the front and back of the stone are both facetted, as shown in the figures. Other gems than the diamond, and also pastes, are however often facetted in the same manner on the front only, and the back is cut in some other mode that will permit of a greater number of facets being introduced; generally the trap cut, or the star cut, is employed on the back, and the stone is then said to have a brilliant cut front, and a trapped back, or a star cut back, as the case may be.

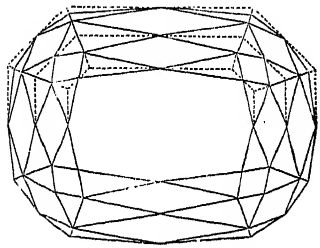
In cutting the full brilliant, the front of the stone is prepared by cutting the table, girdle, and water basil, exactly as for fig. 322; and in forming the back, the eight principal squares are first cut just as in trapping a single height, the culasse is then cut, and lastly, the 16 facets around the girdle, called *under facets* are produced by cutting two triangular facets upon every one of the angles of the eight principal squares, which thus become converted into the irregular pentagons shown in the figures. In facetting the front, the eight foundation squares and the eight skill facets around the table, are cut in just the same manner as for the half brilliant; but in removing the lower angles of the foundation squares, two triangular facets are cut at every angle, exactly the same as on the back of the stone. These facets are by some lapidaries called *double skill facets*, from being cut in pairs, and by others *brilliant facets*, because the rays of light are reflected from their surfaces with greater brilliancy that from any other part of the stone. It will be observed that in the figures the lozenge shape of the foundation squares is irregular, the lower pair of sides being wider than the upper; this form is adopted partly to allow for the small portion enclosed in the setting of the stone, but principally in order to increase the play of light, by making the brilliant facets as large as can be ventured without materially impairing the symmetry of the cutting.

The *split brilliant*, or *trap brilliant*, figs. 334 to 336, only differs from the full brilliant, fig. 332, in the foundation squares being divided horizontally into two triangular facets,

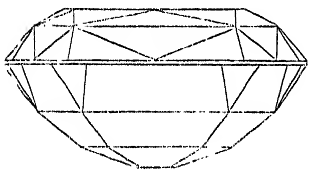
Figs. 334.



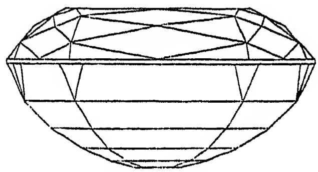
337.



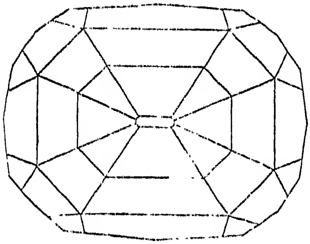
335.



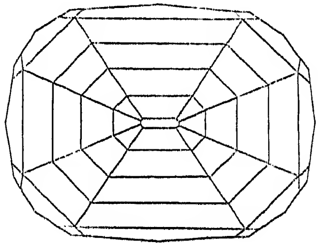
338.



336.



339.



forming an obtuse angle when viewed in elevation, as in fig. 335. In cutting the split brilliant, the face of the stone is prepared by forming two bevels around the margin, which are afterwards converted into squares exactly like the stone trapped in two heights, fig. 325. The upper height of squares is made narrower than the lower; the skill facets, and the brilliant facets are cut in the same manner as for a full brilliant, and are both made to terminate on the ridge dividing the foundation squares into triangular facets. The back of the stone is represented as trapped in three heights of different widths, the narrowest being nearest the culasse. The squares of the trapping are, as usual, placed opposite to the foundation squares on

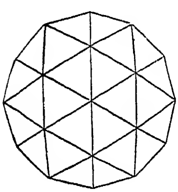
the front, and the row of squares adjoining the girdle has its angles replaced by eight under squares placed opposite to the brilliant facets on the front.

The double brilliant, or Lisbon cut, figs. 337 to 339, is a duplication of the brilliant cut, fig. 332, having two rows of lozenge-shaped squares, and three rows of triangular facets. The two rows of foundation squares are first cut as for the stone contrapped in two heights, fig. 324; and they are afterwards converted into the lozenge shape, by cutting one row of skill facets around the table, one row of double skill facets upon the angles joining the two rows of squares, and one row of brilliant facets around the girdle. The dotted lines in fig. 337 show the angles removed by cutting these facets, by which it will be seen that the row of double skill facets in the middle, removes at the one operation the inner angles of both rows of foundation squares.

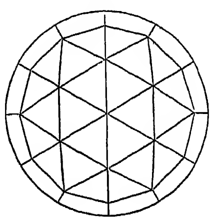
In some few instances a third row of foundation squares is added, by first cutting the stone in three heights, and then cutting three rows of double skill facets in addition to the row of skill facets around the table; but this degree of elaboration is considered to cause so much confusion in the rays of light, as to entirely neutralise the advantage obtained from the greater number of reflecting surfaces, and is seldom resorted to except for concealing defects in large stones.

The rose cut shown in figs. 340 to 344, as previously men-

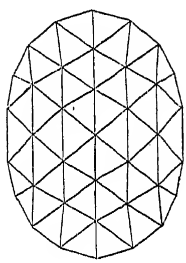
Figs. 340.



342.



344.



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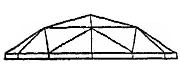
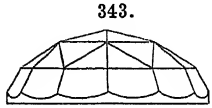


343.



tioned, is employed for those diamonds and other transparent stones that are too thin to admit of being cut on the back;

and sometimes the rose cut is also employed for opaque stones that would derive no additional lustre from the back cutting. The true rose cut consists of twenty-four triangular facets, cut upon a stone having a circular or dodecagonal base, flat beneath and rounded at the top, as shown in fig. 341. The central portion of the stone is cut into six equilateral triangular facets the points of which meet in the center at the summit of the stone, and their bases form a regular hexagon, six other equilateral triangles are joined by their bases to the central facets, and their points rest upon the girdle. The spaces between the outer row of triangles are each cut into two triangular facets, which closely resemble the double skill facets in the brilliant cut.

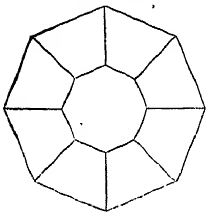
In cutting the stone, figs. 340 and 341, the back is flattened, and the face rounded to the general curve, the central zone of six facets is then cut, commencing with two opposite facets, and when these have been made parallel and of the required size, the intervals are each cut into two facets, care being taken that all the facets are of equal size. The six principal facets in the outer row are next cut; and lastly, the six intervals between these facets are cut into six pairs of double skill facets which complete the rose cut, as applied to diamonds and thin gems generally. Thicker stones, however, are sometimes cut with an additional row of twelve nearly square facets, arranged around the outer row of triangles, as in figs. 342 and 343; every square being equal in width to the base of its adjoining triangle; at other times instead of squares, the outer row is composed of two rows of triangles. The rose cut is also frequently applied to elliptical stones, as in fig. 344; and, as there shown, the central hexagon is elongated, and the triangles are made of irregular forms.

Figs. 345 to 347 represent a stone cut in squares, or trapped in one height on both the front and back, which differ from each other only in the greater thickness of the back, and the culasse being much smaller than the table. This form of cutting is sometimes adopted for small crystals and pastes for cheap jewellery.

Crystals and pastes employed as fictitious diamonds, are generally cut as in figs. 348 to 350. The front is cut as a full brilliant of eight principal squares, upon a regular octagonal

base like the diamond. The back is first cut with a row of eight squares, somewhat like fig. 347; a row of double skill

FIGS. 345.



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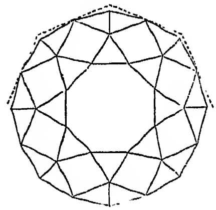

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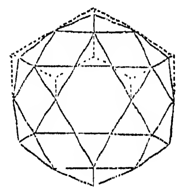

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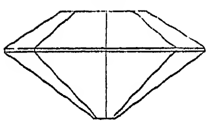

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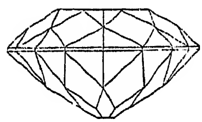

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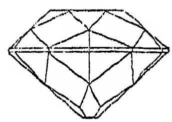

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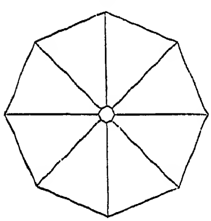

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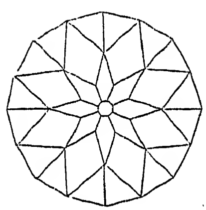

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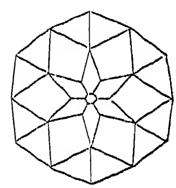
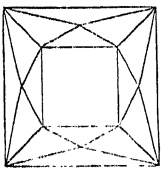


facets are then arranged around the girdle, as in fig. 333; and, lastly, a row of eight facets are arranged around the culasse. These facets are cut upon the angles joining the principal back squares, the points are extended until they meet the double skill facets, and the back facets intersect each other near the culasse, giving the appearance of a star, whence this form of facetting for the back is known as the star cut. The row of facets around the culasse materially increases the brilliancy, and causes the play of light more nearly to approach that of the diamond. Figs. 351 to 353 represent the same form of cutting applied to a hexagonal stone.

The form of facetting called the × cut, shown in figs. 354 to 357, is considered to be a very perfect style of cutting for stones having a square or a regular octagon for their base, as it allows of a considerable number of triangular facets being cut upon the top, and at the same time the table and girdle may be retained of one regular figure. In cutting this form, the

front is trapped in two heights, and the squares thus produced are converted into triangles by cutting one pair of triangular facets upon every angle of the square or octagon. As seen in the figures, these facets extend from the table to the girdle, and meet in the center of the sides. The × cut is seldom applied to other than square or octagonal stones, and for these shapes the back is generally facetted with the star cut, but sometimes octagonal stones are trapped at the back.

Figs. 354.



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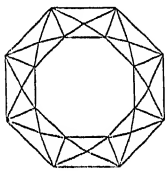

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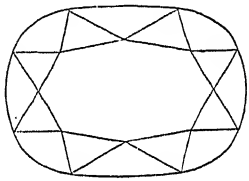
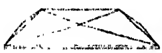


355.



357.

359.

Figs. 358 and 359 represent the *dental cut,* which consists of two rows of triangular facets cut on the top of the stone. The two rows are necessarily interposed, hence the bases of one row of triangles form the margin of the table, and the bases of the second row are placed on the line of the girdle, each row extending from the girdle to the table, as seen in the figures, which show the application of this cut to an elliptical stone having eight principal sides. In cutting this form, the front is first trapped in one height with eight squares, and the figure is completed by cutting eight triangular facets around the table, every facet being placed, as usual, upon one of the angles formed by the foundation squares. The back is generally trapped.

All the different forms of facetting are usually cut by practical lapidaries, without any other guide than the gim peg and cement stick, as shown in fig. 321. The more difficult cases of cutting valuable gems, arise from the irregular forms of the rough stones, or slight imperfections in their substance, and these difficulties require to be combated rather by judg-

ment and dexterity of hand than by mechanical guides. This dexterity once acquired, renders the employment of guides less necessary when the forms of the rough gems are more favourable, especially as the adjustments can be effected more rapidly by the practised fingers than by mechanical means. In the comparatively slow process of polishing the facets on diamonds, a very simple form of guide is adopted, as alluded to at page 176, Vol. I.; but this instrument only serves to retain the stone in position, and all the adjustments of angle are effected by hand, in order that the operator may be enabled to place every facet flat upon the skive, without reference to the particular angle at which it was cut.

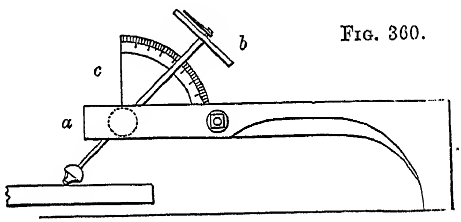


FIG. 360.

Fig. 360 shows a modification of this instrument, contrived by a Geneva lapidary, to adapt it to the cutting of facets at definite angles. The instrument, called a *cadrans*, has two jaws, *a*, which are closed like a vice by a screw passing through them, each of the jaws has on the inside a hemispherical cavity into which a brass ball is fitted; a tube passes through the ball and carries at its upper end a small flat disc, *b*, having on the upper side several concentric circles divided into equal parts. Every circle has a different number of divisions, which are so arranged as to include all the numbers usually required in cutting facets. The cement stick carrying the stone to be cut, is made cylindrical and fits within the tube sufficiently tightly to retain its position during the cutting of the stone, and the upper end of the stick is made square to carry a small index point, by which the divisions on the disc are read off.

The vertical angle of the tube is determined by the quadrant *c*, fixed on one side of the jaws, *a*, and the tube is retained at any angle by closing the jaws upon the ball. The center of

the quadrant is supposed to be in the center of the ball, and the arc is divided as usual into 90 degrees, the upper division is marked 0, and the lower 70, the remainder of the arc being hidden by the jaw. When the tube is fixed at 0, the cement stick is vertical, and this position serves for cutting the table or the culasse; on fixing the tube at 20 degrees, all the facets cut in this position will be inclined at that angle, and the number of facets around the stone will be determined by twisting the cement stick in the tube, until the index marks the required division on the disc, *b*.

Fictitious gems are prepared in a variety of ingenious methods, sometimes stones of inferior value are modified in their colours by heat and substituted for more valuable gems, as in the case of the zircon, which is sometimes rendered colourless by heat and substituted for the diamond. The colours of carnelian are principally given by heat. In Phillip's Mineralogy, it is stated, that carnelians, when found, are of a blackish olive passing into a grey. "These are first exposed to the sun for some weeks, and then placed in earthen pots and subjected to heat, which gives them the colours which constitute their value in jewellery." Carnelian, when imported into England, is generally of a red colour, and when the colour is too light it is sometimes deepened by putting the stone in an iron pot and gradually bringing it to a red heat. Yellow carnelian is by the same means rendered red; but the effect of heat upon the white variety is to render it more opaque, and advantage is sometimes taken of this circumstance to give white carnelian the appearance of the white onyx. The various colours of agates are, in some cases, more fully developed in the same manner; in others the agates are soaked in oil for two or three hours, the oil penetrates the agate and is afterwards carbonised within the stone by exposing the latter to the fumes of heated sulphuric acid. Nitrate of silver is also sometimes employed for staining agate and other stones. Agate indeed is rarely worked in its natural state or until stained, which curious process is possible from the unequal hardness of the different layers that compose the stone; the white and lighter coloured are considerably denser than the intervening

material, the latter absorbs the stain with comparative ease, the lighter layers barely and the white not at all, and their contrast thus becomes the more pronounced. At Oberstein, the principal seat of the manufacture of ornamental agates and onyx, the stones are stained red, blue, green and black, the last being the most common for beads, brooches and other small works. For black the agate or onyx is boiled for some hours in a solution of about equal parts of molasses and water under pressure in a steam boiler and then in a similar manner in sulphuric acid diluted by a small proportion of water; after the stones are dried and cooled much of the mixtures exudes like dew. Blue is obtained by treatment with oxide of manganese, and red and green with salts of iron and copper.

Pastes are, however, the most frequent substitute for precious stones. The foundation of all pastes is a superior colourless glass called *strass*, made from very pure materials, and afterwards coloured by the addition of metallic oxides in much the same manner that ordinary coloured glass is made, except that the process is more carefully performed throughout. The French are considered to excel in the preparation of pastes, and a variety of recipes for the manufacture of pastes, derived from various French authors, are given in Dr. Ure's "Dictionary of Arts," p. 631, and also in Gill's "Technical Repertory," vol. ii. p. 308.

Metallic foils made of thin sheet copper silvered and burnished, and afterwards coated with transparent colours mixed with isinglass size, are often employed by jewellers to improve the brilliancy of pastes and inferior stones. The foil is enclosed in the setting and entirely covers the back of the stone, to which it imparts much of its own brilliancy. When it is desired to modify the colour of the stone, a foil of a lighter or darker tint is used according to circumstances. Crystals and pastes, set as imitation diamonds, generally have a piece of silvered foil at the back.

Painting is sometimes resorted to for counterfeiting topazes, and other gems; in this case, a colourless stone such as crystal is employed, and the back of the stone to be enclosed in the setting is painted with the colour removed from a piece of foil, and another piece of the same foil is placed behind the stone in the setting to improve the brilliancy. The reflection

of the colour from the back of the stone is so uniformly diffused throughout its substance that, even upon close observation, the unpractised eye fails to detect the absence of colour in the body of the stone. In removing the colour from the foil, the latter is gently warmed over a candle, and, while warm, the colour is worked up with a moistened brush and immediately applied to the stone, care being taken to cover every portion of the back, particularly the angles formed by the meeting of the facets, as, should the smallest speck remain uncoloured, it would reflect a ray of white light that would altogether mar the effect. The painting of these fictitious gems is sometimes so successfully executed, that only those persons thoroughly conversant with precious stones, are enabled to distinguish between the real gem and the counterfeit so long as the stone remains in the setting.

Doublets are a more elegant and substantial application of the method of counterfeiting gems by coloured backs and transparent fronts. In doublets, the front and back are made in two pieces, cemented together on the line of the girdle. The front is made of a colourless stone, and the back of a coloured paste; the two surfaces to be placed in contact are first ground quite flat and smooth, to fit each other accurately; they are then cemented together with a very thin layer of clear mastic, and the doublet thus prepared is cut as a single stone.

In real gems advantage is sometimes taken of the power of a coloured back to give colour to a colourless front. It occasionally happens that a gem may be partly colourless and partly coloured. In this case, instead of dividing the stone, the coloured portion is placed at the back, and, if possible, the stone is so cut that the table shall be parallel with the imaginary line dividing the two portions; and if the stone have much natural brilliancy, it is not imperative that the coloured portion should extend to the girdle, as a comparatively small piece, properly placed, will serve to colour the entire stone. A striking illustration of this was observed by the writer in the case of a sapphire, the bulk of which was perfectly colourless, and a small part only of a deep blue colour. This gem was about one-sixth of an inch in length, and nearly of the same measure from the table to the culasse, the great propor-

tional depth having been adopted, in order that the colour might be reflected throughout the body of the stone from the small blue portion, which was scarcely larger than the head of an ordinary pin, and yet in consequence of its being situated exactly upon the culasse and extending a small distance up the back facets, the blue colour appeared to be uniformly diffused throughout the stone when viewed from the front, although at the time of inspection the stone was not set. When viewed from the back, the body of the stone appeared quite colourless, with a small speck of a dark blue colour on the culasse. Some management is, however, required to obtain this result, as, if the stone have too much width or spread the edges will appear colourless, and in extreme cases the blue will only show as a dark central spot. Owing to the various degrees of brilliancy in different stones and the variation in the size of the coloured portion, no invariable rule can be adopted for the spread of the stone relatively to its depth; the proportions are therefore obtained by trial, the spread being gradually reduced without interfering with the thickness, until the desired result is obtained.

SECT. III.—LAPIDARY APPARATUS FOR AMATEURS.

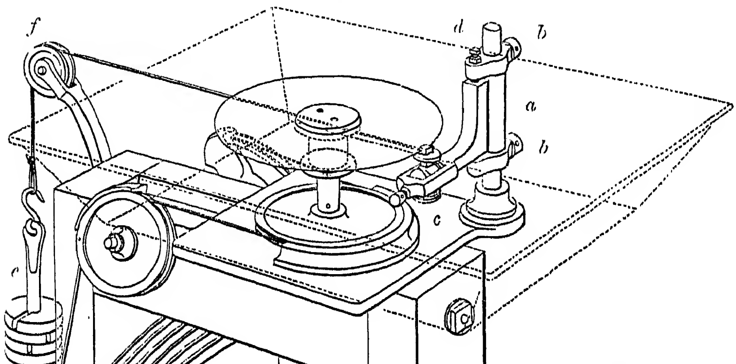
This is sometimes similar to that described in the preceding section, but to avoid the inconvenience of having to use one hand to turn the wheel and to keep the other steady in holding the stone, which requires some practice, the laps are more generally driven by a foot wheel and treadle; the general arrangement of the apparatus then closely resembles the horizontal grinding machine shown in fig. 52, in which the upper surface of the lap is not obstructed by a vertical spindle, as in the lapidary's bench, fig. 312, and the same spindle is employed for all the different grinding and polishing wheels, which are screwed upon it.

The less difficult parts of lapidary work, such as producing a flat or a rounded surface on a pebble, may be executed with facility on the horizontal grinding machine, which is frequently converted into a simple lapidary apparatus by the addition of a slicer and trough to catch the water thrown off the lap. But for the more elaborate processes, such as cutting

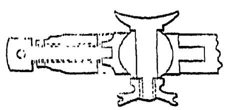
a stone into thin slices and facetting gems, other additions have been made, in which the principal difficulties of manipulation are removed by the introduction of guides for slitting and facetting, and the apparatus then assumes the more complete forms shown in figs. 361 and 363.

Fig. 361 represents the amateur lapidary apparatus fitted

Figs. 361.



362.



with the crane, or swinging arm, for presenting the stones to the slicer. The foundation of the apparatus exactly resembles that described fig. 52, except that the rectangular trough, indicated by the dotted lines in fig. 361, occupies the place of the upper platform in fig. 52, and the lower platform has an enlargement at its right-hand corner for the support of a strong cylindrical pillar that carries the socket *a*; this socket slides vertically upon the pillar, and admits of being fixed at any height by means of the binding screws *b b*. The swinging arm, *c*, is supported on the socket by two center screws, one of which is seen at *d*; these allow of the horizontal motion of the arm, which has near the front a rectangular opening in which is fitted a ball and socket joint, and a binding screw at the extremity of the arm serves to retain the ball at any desired angle. The ball is perforated with a square hole, into

which is fitted the square stem of a metal cup for the reception of the stone to be sliced. This portion is shown separately in fig. 362; and, as there seen, the stem of the cup passes through the ball, and is fixed by the milled nut beneath. The arm is drawn towards the slicer by the weight *e*, a line from which passes over the pulley *f*, fixed on the end of the frame, and is attached to a small stud screwed into the under side of the arm.

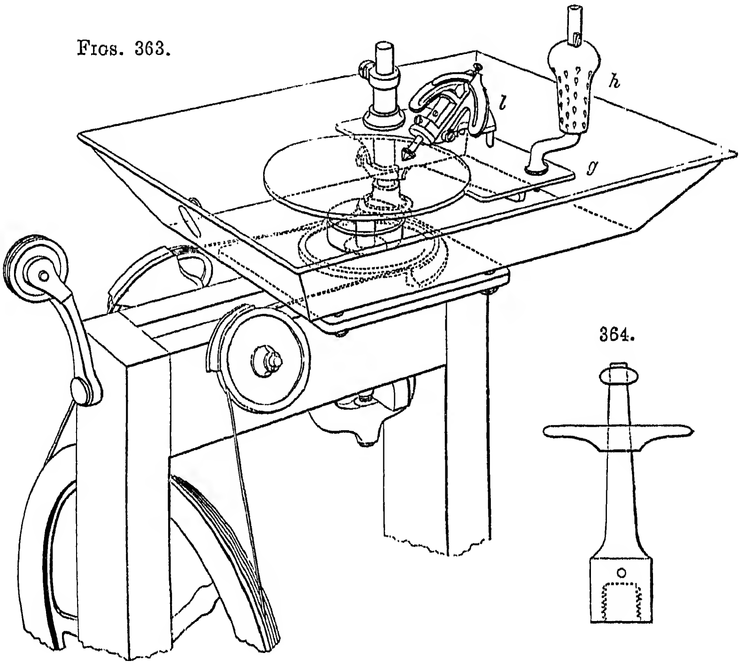
In slitting a stone with this apparatus, it is first cemented in a cup of appropriate size, the stone and cup being both heated nearly to the fusing point of the cement. The stone is placed with the intended line of division as nearly horizontal as convenient, and when the cement is set, the cup is inserted in the ball and fixed by the milled nut. The position of the ball is then adjusted until the line of division is exactly horizontal, and the precise height is regulated by sliding the socket upon the vertical pillar. When the adjustments have all been satisfactorily made, the binding screws are tightened and the weight is attached to the line; this completes the preparation so far as the adjustment of the apparatus is concerned; and when one cut has been made, if the stone is required to be cut into parallel slices, it is only necessary between every cut to shift the socket *a*, upwards, a distance equal to the thickness of the intended slice. The slicer requires to be charged with diamond powder, and lubricated with the oil of brick or with paraffine oil, as previously explained; and the weight should also be proportioned to the size of the stone. For ready adjustment to meet this last particular, the weight is made in detached discs with central holes that fit upon a cylindrical rod to which the line is attached. The rod is flattened near its upper end, and every disc has a radial slit or mortise extending from its central hole to the edge. In applying the weight, the mortise in every disc added is passed over the flattened portion, and the central hole is slipped down the cylindrical part of the rod, which latter is too large to pass through the slit.

The apparatus for cutting facets is represented in fig. 363, the upright pillar at the back is here employed to support the platform *g*, and upon this is mounted the gim peg *h*, which may be employed for cutting facets in the same manner as

that used by practical lapidaries; but the instrument for cutting facets shown at *l*, is a more exact contrivance, far better adapted for the purposes of the amateur, as the facets may be cut to any required angle with great precision, and the operator has only to determine the size of the facets by suspending the process when each is sufficiently developed.

The basis of the instrument is exactly the same as in those for setting straight and angular turning tools, shown in fig. 55,

FIGS. 363.



364.

and fig. 64; indeed the same instrument might serve all three purposes if fitted with suitable beds or sockets for the reception of the different objects to be ground. In the instrument for grinding facets the rectangular socket G, shown in fig. 64, is replaced by a frame, which is mounted in the same manner, and is therefore capable of being set to any vertical or horizontal angle. This frame, shown separately on a larger scale in fig. 365, carries a steel spindle, which is capable of revolving within bearings and may be fixed at any position by the binding screw, *n*. A hole bored up the center of the spindle

extends nearly through its length, and into this is fitted the cylindrical stem of the cement cup, *p*, intended for the reception of the stone. The cement cup is retained in the spindle by the small binding screw, *q*. For determining the position of the spindle, a cylindrical flange *r*, is fixed on its front end and the edge of this flange is provided with two circles of graduations, the one containing 96 divisions, the other 60; and the divisions are read by an index fixed on the top of the frame.

The annexed table shows the divisions that may be obtained from the two circles of 96 and 60, which will be found sufficient for general purposes.

In	2 parts	by 48	in	96	In	8 parts	by 12	in	96	In	20 parts	by 3	in	60
,,	3 ,,	32	,,	96	,,	10 ,,	6	,,	60	,,	24 ,,	4	,,	96
,,	4 ,,	24	,,	96	,,	12 ,,	8	,,	96	,,	30 ,,	2	,,	60
,,	5 ,,	12	,,	60	,,	15 ,,	4	,,	60	,,	32 ,,	3	,,	96
,,	6 ,,	16	,,	96	,,	16 ,,	6	,,	96	,,	48 ,,	2	,,	96

The first column contains the number to be obtained; the second, the number of divisions to be taken in the circle denoted by the third column. In cases where the same intersection could be obtained in both circles, the lowest has been selected for easy reading.

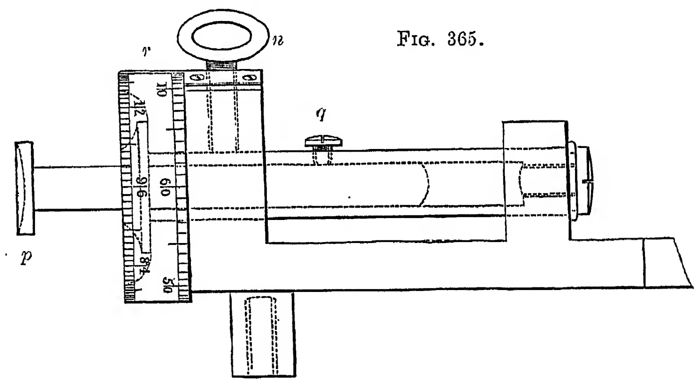


FIG. 365.

In facetting with the arrangement fig. 363, the stone is prepared by cutting it to the general contour by hand, in the same manner as practised by lapidaries, the stone being fixed upon an ordinary cement stick, the flat surface for the table is first cut, and then the girdle. The front and back of the stone are next rounded nearly to the required shape, and water basils

cut, to denote the width of the principal facets. The stone is then removed from the cement stick, and fixed to the cup *p*, shown in fig. 365, in the same manner that it was previously attached to the cement stick; but it is here of still greater importance that the stone should be placed exactly in the center of the cup, and quite horizontally to its axis, otherwise, the facets will be cut at irregular angles. To assist in determining the position of the stone before it is finally cemented, it will be found convenient, after the cement has been attached to the cup, to press the cold stone into the cement while the latter is still warm and soft. This serves to form the cement correctly to the shape of the stone, and permits the position of the latter to be more deliberately inspected and if necessary corrected. When the position of the stone is found to be satisfactory, the latter is warmed over the candle and the surface of the cement fused just sufficiently to adhere to the stone, which may then be slightly pressed into the cavity; the cement is lastly worked into the angles with the fingers, which are slightly moistened, to prevent the adhesion of the cement.

The stone is attached to the facetting instrument by sliding the stem of the cement cup *p*, into the spindle, as seen in fig. 365, and fixing it by the small binding screw *q*. The projection of the stone from the spindle should be so adjusted that the latter may be exactly vertical, when the plane, C, fig. 64, is fixed at 0, on the graduated arc, B, and the face of the stone rests upon the lap, while the feet of the instrument are supported upon the platform. The correct position of the instrument is most readily estimated, by observing that the base piece, A, is parallel with the platform. With large stones, it will sometimes be found desirable to effect the adjustment by elevating or depressing the platform, instead of adjusting the projection of the cement cup; but with small, it will be generally found more convenient to place the platform level with the surface of the lap, under the test of a straight edge, in order that no after-adjustment of the instrument may be required when the laps are exchanged for smoothing and polishing.

The facets are cut in the same order that is adopted in cutting corresponding forms with the gim peg, which has been

already explained in the second section; but the vertical inclination for every row of facets is obtained by adjusting the plane C, shown in fig. 64, upon the graduated arc B, and the number of facets in every row is determined by the divisions on the flange of the spindle shown in fig. 365.

Thus, in cutting a stone with a brilliant-cut front, and a star-cut back, like fig. 349, the plane C is placed at 0, on the arc B, for cutting the culasse. The principal row of eight squares at the back is cut with the plane, C, inclined to about 50°, and the spindle is fixed successively at the divisions 12, 24, 36, 48, 60, 72, 84, and 96. The row of 16 double skill facets around the girdle is cut with the plane, C, inclined to about 45°, and the divisions employed are 3, 9, 15, 21, and so on to 93, in order that the double skill facets may terminate upon the angles of the principal squares. The row of eight facets around the culasse are cut with the plane, C, inclined to about 55°, and the socket is fixed at the divisions 6, 18, 30, 42, &c., a facet being cut at every twelfth division, as in the row of primary squares; but, in order that the two rows of facets may be interposed, the intermediate numbers are employed. In cutting the front of the stone, the same series of divisions are employed for determining the numbers of facets, and the vertical angles are, 0, for the table; 50° for the foundation squares; 40° for the skill facets; and 60° for the brilliant facets.

Fig. 364 represents a supplementary spindle which is screwed on the vertical mandrel of the machine, fig. 361, to carry the smaller mills and balls that are employed for grinding and polishing concaves, mouldings and other details. Two of these small grinders are shown upon it, held, like all, by the simple plain fitting of their central apertures upon the tapering shaft of the spindle; they are charged and used in the manner already described, the work presented to their edges held in the fingers.

CHAPTER XI.

GEM AND GLASS ENGRAVING. GLASS ETCHING.

SECT. I.—SEAL AND GEM ENGRAVING.

Gems, precious stones, glass and other hard substances that do not admit of the application of tools with cutting edges, are engraved either in relief or in intaglio, by the employment of small revolving wheels charged on their edges with fine abrasive powders, and lubricated with oils or water. The object to be engraved is applied to the lower edges of the wheels with the fingers, unassisted by any mechanism, being twisted about during the process so as to expose every part of the device successively to the action of the little wheels, which gradually produce small hollows and grooves that are in section nearly counterparts of the sections of the tools employed in their formation. The wheels are made in a great variety of sizes and shapes according to the forms they are intended respectively to produce, and with the abrasive powders they constitute the only cutting tools applied in these interesting and delicate processes of abrasion.

For engraving all hard stones the wheels are made of iron charged with diamond powder, and are lubricated with the oil of brick or with paraffine, and when the engraved surfaces are polished, this is effected with copper wheels charged with rottenstone and water. For engraving glass, similar but larger tools made of copper supplied with emery and olive oil, are employed, and the polishing is effected with leaden tools with pumice stone powder and water. The processes of engraving gems and glass are very similar and differ principally in the greater depth and elaboration of the designs in gem engraving, which latter will be first described and the principal peculiarities of glass engraving will be afterwards alluded to in a separate section.

The most extensive application of engraving on stones is the sinking in intaglio of armorial bearings on seals, which is

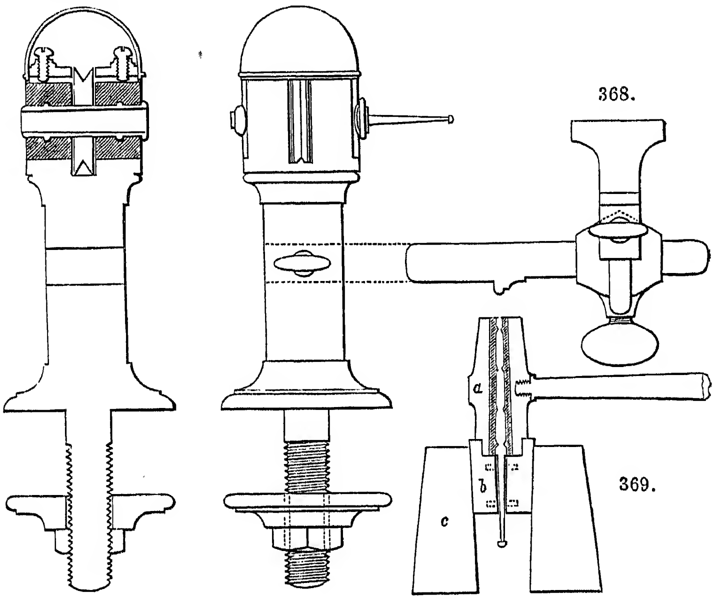
called seal engraving, and the engraving in intaglio of more artistic subjects on gems and stones is called gem engraving. When the design is engraved in relief the process is called cameo cutting, but the apparatus and manipulations are nearly the same in all three branches of the art. The ordinary practice of seal engraving will be first described, followed by some observations on the more graceful art of gem engraving, and the practice of cameo cutting will be afterwards adverted to.

The wheels employed in seal engraving are called *tools*, and are made as shown in fig. 377, with long conical stems that are fitted somewhat like chucks into the hollow mandrel or *quill* of a miniature lathe head, called a seal engraver's engine, the most usual form of which is shown one-fourth of its real size in fig. 367, this is mounted upon a stout table hollowed out in front somewhat like a jeweller's bench, and either about 2 feet 6 inches or 3 feet 6 inches high, according as the operator may prefer to sit or stand to his work. The engine is driven by a light foot wheel from 18 inches to 2 feet diameter. The tools being of very small diameter, little power is required; a rapid motion is, however, requisite for some parts of the work, and a steady position of the body is at all times of the first importance; the treadle is, therefore, jointed just beneath the heel of the operator, who is thus enabled to give a rapid motion to the wheel with but little movement of the leg. The entire apparatus should be quite free from tremor and with this view the bench is made very strong and, if possible, firmly attached to the floor. In some cases the foot wheel is mounted in a frame independent of the bench, in order that any vibration in the wheel or its axis may not be communicated to the tools.

Fig. 366 shows the section of the engine, which consists of a brass pillar about 6 inches high, having at the base a central bolt which passes through the top of the bench and is retained by a nut and washer beneath. The upper part of the pillar has two openings, which cross each other at right angles, and serve for the reception of the pulley and bearings of the quill. The bearings are generally cylindrical and made of tin or

pewter cast upon the quill; each pair of bearings is adjusted to fit the quill by a set screw, passing through a brass cap screwed on the top of the pillar. The quill is of steel, about 2 inches long, and half an inch diameter; it passes entirely

FIGS. 366. 367.



368.

369.

through the bearings, all end-play in which is prevented by two small beads turned in the solid upon its exterior.

The quill is bored with a slightly conical hole, measuring about five-sixteenths of an inch in diameter at the front end and one quarter of an inch at the back. A small angular groove, about half an inch long, is filed in one side of the bore at the front end, for the reception of a corresponding feather on the tools, which serves to prevent the latter from slipping round in use, and also to ensure their being always placed in the same position in the quill. The pulley, which measures about one inch and a half in diameter, is generally made in the same piece with the quill, and when in its place is almost concealed in the upper part of the pillar. A small hemi-spherical cap is fitted on the top of the pillar, to exclude all dust or grit from the bearings, and it is also very generally

used as a rest for steadying the hand during the process of engraving.

In some cases the quill is made 3 or 4 inches long, and mounted, more like an ordinary lathe mandrel, in a conical steel collar at the front and on a back center also of steel. In this case the conical hole for the tools extends about 2 inches up the quill, and a central mortise is made at the bottom of the hole for the insertion of a lever or wêdge by which the tools are forced out, or otherwise a collar is cast upon the front end of the tools, and they are released with a forked lever.

The tools are made of iron wire, prepared from the softest stub iron and carefully annealed, to render them as soft as possible. The conical plug that fits into the quill of the engine is formed by casting around the stem of the tool a corresponding cone of some easily fused metal, as tin, pewter, or lead hardened with a little antimony. The moulds for casting the conical plugs are made in various forms, but the general construction will be sufficiently obvious from an inspection of the section shown in fig. 369, in which *a* represents the body of the mould in which the plug is cast; *b*, the metal socket in which the tool and mould are fixed to retain them both central; and *c*, the wooden block for the support of the whole. The part *a* is made a little longer than the quill, and is fitted in the middle of its length with a stem and wooden handle, which give it somewhat the appearance of a hammer. Throughout its length there extends a central conical hole, the angle of which is exactly a copy of that in the quill, (both holes being generally formed with the same tools,) and at the larger end of the hole is filed an angular groove to form a feather to fit in the corresponding groove in the quill. The end of the mould *a*, having the groove, has a short cylindrical neck turned on the outside, and concentric with the hole, and this neck is fitted into a corresponding recess in the upper part of the socket *b*. The socket is made in halves, fitted together with steady pins, and has a central hole for the reception of the tools and the exterior of the socket is made rather conical and fits into a corresponding hole in the wooden block *c*.

In preparing the tools after the wire has been annealed,

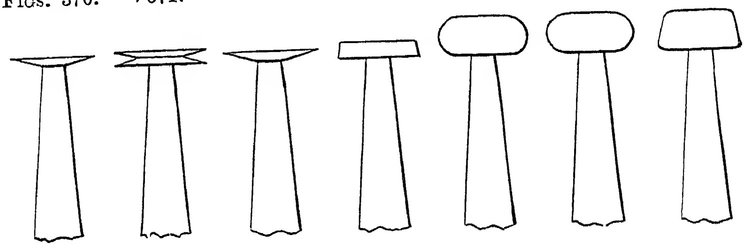
they are first roughly filed into form, the small discs are filed out of the solid, the stem that projects from the end of the quill is made round, rather conical, and a little smaller at its larger end, than the hole in the socket. The shank that is to have the conical plug cast upon it is made square, slightly taper, and with a few notches roughly filed in the angles in order that it may be firmly held in the casting. The socket *b* is then separated, and the stem of the tool is made to fit the central hole, rather tightly, by winding a slip of paper around it. The socket is then closed, inserted in the wooden block, and pressed tightly down, when the conical form of the exterior of the socket and of the hole, ensure a firm grasp upon the stem of the tool. The mould *a* is then fitted into the recess in the socket *b*, which ensures the square stem of the tool being central with the conical hole, and the fluid metal is poured in from a small ladle. When the metal is set, the socket is removed from the block and separated, any superfluous metal that may have lodged on the upper end of the mould is filed off, the tool is then pushed out of the mould, and is ready to be inserted in the quill. It is of primary importance that the tools should run perfectly true in the engine and, therefore, after the plugs have been cast the tools are fixed in the quill and turned to the required forms with small gravers applied in the usual manner. The rest for turning the tools is shown in fig. 368, and much resembles that employed in the turn-bench of the watchmaker; when in use the horizontal bar is passed through a mortise in the brass standard, and retained in its position by a binding screw.

The forms and sizes of the tools employed in seal engraving are very numerous to adapt them to the various parts of the different devices, but the general shape is that of little discs more or less rounded on the edges, which is the part almost exclusively used. Some of the tools for cutting fine lines are made almost as thin on the edge as a knife, others rather thicker and more rounded on the edge, are employed for thicker lines. For sinking large shields and similar purposes, the tools are considerably rounded, being in some cases made almost spherical, as a tool with a rounded edge is found to cut more rapidly than one with a more nearly flat edge; and, therefore, a rounded tool is generally used for removing the

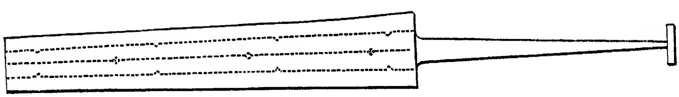
principal bulk of the material in large works, and a tool with a flatter edge is used for smoothing the surface. For flat surfaces, the tools are made with flat edges, and to enable them to be applied to deep works without the stem interfering with their action, the diameter of the front of the tool is generally made somewhat smaller than the back, so as to make the edge rather conical, as seen in fig. 373.

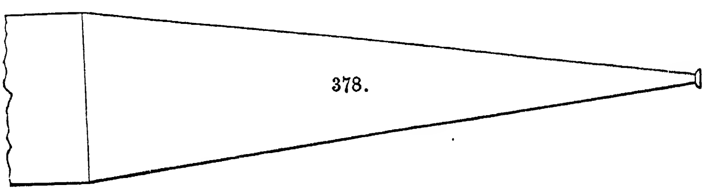
Figs. 370 to 376, represent some of the most usual shapes

FIGS. 370. 371. 372. 373. 374. 375. 376.



377.





378.

of tools, but the sizes are greatly magnified for distinctness, the tools shown in figs. 370 to 373, being seldom larger than one-sixth of an inch in diameter, and tools of nearly all the shapes are made very much smaller, some of them so small as not to exceed the $\frac{1}{150}$th of an inch in diameter, these can hardly be distinguished by the naked eye from the stem of the tool, which appears to terminate almost in a needle point, although on examination with a magnifier the discs are seen as distinctly developed. The general form of the point of these minute tools is shown in fig. 378, which represents the disc and part of the stem magnified about fifteen times. These exceedingly minute tools do not admit of being formed of so

small a size by the turning tool alone, they are therefore reduced as small as possible with a fine file, and are afterwards employed for works of a little larger size, until they become sufficiently small from wear to be used for making very minute dots, such as sometimes occur in the markings of the eyes in figures of men or animals, the full lengths of which figures do not exceed one quarter of an inch.

All the tools are required to have tolerably smooth surfaces, and to be quite free from ridges or hollows. In use they are liable to be worn into minute hollows, called *creases*, and should one of these be formed in the side of a thin tool, such as fig. 370 or 372, it would be almost certain to chip off a fragment of the stone so soon as the crease was embedded in the cut. To prevent the formation of creases in thin tools, the seal engraver makes frequent use of a fine file to smooth the sides of the disc, which at the same time serves to prevent the edge of the tool from becoming thickened as it is reduced in diameter by wear.

The tools are charged with fine diamond powder, prepared as described, in the mortars shown in figs. 313 to 315. Seal engravers generally keep the diamond powder in the mortar in which it was ground; the powder is mixed into a pasty condition with olive oil, and small quantities are taken out as required. Sometimes the diamond powder or paste is kept in small quantities in a little conical cup, and is supplied to the tool, either by holding the cup to the tool, or a little of the diamond powder is removed with a small spatula, and held to the edge of the tool. More generally, however, the seal engraver wears on the forefinger of the right hand a ring made of a strip of tin, to which are soldered two little shallow cups, about half an inch in diameter, one of which contains a very small quantity of the diamond paste, the other, one or two drops of the oil of brick or a little paraffine oil. The diamond paste is occasionally applied to the extreme edge of the tool while it is slowly revolving, the tool is then moistened with the paraffine or oil of brick and the cutting is proceeded with, until the lubrication is nearly expended, when the tool is again moistened. Should the tool be allowed to become too dry, the diamond powder would become detached from it, and instead of the stone being cut the tool itself would be abraded,

and as either lubricant is very volatile it requires to be frequently applied. Some artists prefer sperm oil for lubricating the tools but, unless carefully prepared, it is liable to become thick and impede the cutting action.

The stones are always previously prepared to the general form by the lapidary, and frequently they are set by the jeweller before they are engraved, in either case they are too short to be conveniently held in the fingers, they are therefore mounted on a handle or stick about five inches long and three-quarters of an inch diameter. If the stone have not been set, it is fixed with lapidary's cement upon the wooden handle, and to prevent the cement from adhering to the fingers it is sometimes coated with sealing-wax. But if the stone have been previously set, it is inserted in a notch made in a piece of cork, or soft wood, that is frequently inserted in the end of a short length of bamboo of appropriate size. When the stones are hard and have been previously polished on the surfaces that are to be engraved, the latter are roughened by rubbing them upon a soft steel plate charged with a little diamond powder and oil; an ordinary plane iron when annealed is often used as the plate. Sometimes the polish is removed from soft stones by rubbing them upon a leaden plate charged with emery, but the steel plate and diamond powder are more generally used as they serve equally well for hard or soft stones. The roughened surface of the stone is required partly because the tools penetrate more readily therein, and are less liable to slip, but principally to enable the outline of the device to be sketched upon the stone with a brass point, which is abraded by the rough surface and leaves a distinct line. In drawing the design upon the stone, the general outline alone is first carefully sketched, the entire surface enclosed within the outline is then sunk, and the details of the design are afterwards sketched and sunk in succession.

For example, in engraving a shield with quarterings upon a seal. The outline of the shield is first drawn with the brass point, this is then dotted round with a small tool, such as fig. 370, having a thin edge, and called a *sharp* or *knife* tool. The dots, which are about the thirtieth of an inch long and about half that distance asunder, serve to secure the outline and prepare a path for a thicker tool with a rounded edge,

such as fig. 372, with which the outline is perfected. The bulk of the material, within the outline, is then removed with a thicker and larger tool, having a rounded edge like fig. 374; the larger tool operates more rapidly and is also less liable to leave the surfaces irregular, and therefore as large a tool is employed as can be conveniently applied to the purpose. When the body of the shield has been sufficiently sunk, its surface is smoothed with a smaller and flatter tool, like fig. 373, which cuts more smoothly and can also be applied closer into the angles. The fine lines for the quarterings are next sketched, and cut with the sharp tool, and the figures or bearings on the quarterings are afterwards sketched and sunk in succession. If, as frequently happens, two of the quarterings are similar in design, they are sketched and cut together, in order to avoid the frequent change of tools, and also to ensure greater similarity; the same tools being used for corresponding parts of the design. The bolder portions of the bearings are cut first, and the smallest details are left to the last. Should the escutcheon have a shield of pretence, this would be sunk after the quartering lines had been cut, and if supporters and garniture were required, the entire outline would be first sketched, and the whole advanced equally, so as to keep the general effect uniform.

The cutting of the fine parallel lines on the field, called colour lines, presents considerable difficulty, as they are very shallow, and to give them a uniform appearance requires much care and a light but steady hand. To assist in cutting these lines equi-distantly, a tool is used, having two knife edges, as shown in fig. 371, called a colouring tool. The front edge of this tool is used to cut the first line to the required depth, and the second line is at the same time marked out by the back edge; at the next progress the second line is cut to the full depth, while the third line is marked in the same manner and so on; the lines being cut in succession from right to left, in order that the operator may be enabled to watch the progress of the tool throughout, and the stone is held in an inclined position to cause the greater penetration of the front edge of the tool. The colour lines are sometimes cut before the bearings are sunk, but sometimes they are left until nearly all the other details have been completed, the latter course is

adopted in order to avoid the risk of injuring the colour lines should the stone happen to slip in cutting the bearings, but the difficulty of cutting the lines straight and equi-distant is increased, owing to the want of continuity in the surface, and the tool is liable to cut deeper at the edges of the sunken portions. On this account in the best works the colour lines are usually cut before the bearings, but greatly increased care is then required in cutting the latter. When the engraving is quite finished, the flat surface of the stone is finally repolished with rottenstone and water, applied on a pewter lap exactly after the manner described in the chapter on lapidary work.

During the entire process the seal engraver watches the progress of the work through a lens of from 1 to 2 inches focus, which is mounted upon an adjustable stand, like that used by watchmakers, and placed immediately over the tool, and the work is occasionally brushed to allow of its inspection; but the operator depends also very much upon the sense of feeling for estimating the position of the work, and upon hearing for judging of the progress of the tool. To enable him to ascertain the depth and general effect of the intaglio, he occasionally takes impressions in a black wax, made of bees-wax and fine charcoal dust, the latter is sifted through muslin and well worked into the wax with the fingers; but the wax when used is liable to adhere to the fingers, and a preferable method is to employ a small piece of blue modelling clay.

For roughing out the work with large tools, as in sinking the body of a large shield, the engine is driven rapidly, and the stone is applied with moderate pressure; in applying the smaller tools the speed employed is slower, and the pressure is less; and for the smallest tools used in cutting the details, the pressure is very slight, and the engine is driven still slower. For greater steadiness in finishing, the seal engraver sometimes puts the foot wheel in rapid revolution, and then, removing his foot from the treadle, stands firmly on both feet while he applies the work until the tool comes nearly to rest; the foot wheel is then started again, and so on.

From the circular forms of the tools, curved lines and rounded forms, such as are met with in animals, ornaments and drapery are more easily executed than designs composed

of straight lines, which are cut most readily with tools of as large a diameter as can fairly be applied; but large tools cannot be employed for cutting the corners deeply, and therefore small tools must be used for finishing such parts. To give definition to the engraving, the edges should be left nearly vertical, the amount of bevel required for the relief of the impression, even in deep works, being scarcely perceptible. Fine lines having sharp curves, such as the hair strokes in writing, are very difficult to engrave; they require very small knife-edged tools, and the stone must be applied with great steadiness and delicacy; the bolder lines in German text initials are much more easily managed.

In applying the work to the revolving tool, the stone mounted on the stick is supported and guided in both hands, the stick being held almost vertically below the tool, with the face of the stone upwards, so that both the tool and work are constantly under observation. The stone requires to be held with great firmness, but yet to be applied with exquisite delicacy, especially in cutting the minute details, and considerable practice is required to overcome the difficulties of presenting the stone to the tool with both decision and freedom. To give steadiness to the arms of the artist, they are supported upon the bench, but the position depends partly upon the form of engine employed and partly upon the habit of the individual. When the form of engine represented in fig. 367 is employed, the palm of the left hand is generally rested upon the hemispherical cap of the engine, while the forefinger and thumb surround the revolving tool, and grasp the upper end of the stick on which the stone is mounted. The thumb and forefinger of the right hand grip the stick just below those of the left, and the right elbow is supported on a cushion about 6 inches diameter; this position gives considerable steadiness to the hands, and allows of a free motion in the fingers between which the stick is, as it were, suspended; it is, however, rather adapted to small than to large stones.

When the engine is made more in the form of a lathe head, and overhangs the pillar, a different position of the left hand is generally adopted. In this case the left elbow is supported upon a cushion in the same manner as the right, the two elbows being widely separated to lower the hands beneath the

tool and give a wide base to the arms. The left hand is rested against the under side of the overhanging frame, and in some cases the right wrist is supported upon a wooden rest, about 6 inches high and 2 inches diameter, having a hemispherical top to allow of the free motion of the wrist in all directions, and the base of the rest is enlarged to about 4 inches diameter, for greater steadiness. The choice of position is not very material, and depends principally upon habit; but those artists who are accustomed to one position cannot conveniently adopt another. The point of greatest importance is, that both hands should be perfectly steady, and capable of being moved in all directions with great freedom. The wooden rest gives great steadiness to the right wrist, but is liable to interfere with the free motion of the hand, it is, therefore, often dispensed with except for very delicate works.

The general position of the stick is nearly vertical, so as to keep the surface of the stone just sufficiently inclined to prevent the stem of the tool coming in contact with it. In dotting the outline, or cutting shallow works with large tools, the stone may be held quite horizontal; but in cutting deep and delicate works, or sharp angles, very small tools must necessarily be employed, and the stone then requires to be considerably inclined in order to allow the edge of the tool to penetrate to the bottom of the cavity without risk of the stem being brought into contact with the surface of the work. In all cases in which the stone can be kept horizontal the process of gem engraving is comparatively easy, and the principal difficulties met with occur in cutting the curved outlines, and in making a sunk surface quite flat. As previously mentioned, the edges of sunk surfaces should be made nearly perpendicular to give definition to the impression, and the outlines are cut with a thin tool like fig. 372, in which the face of the tool is flat, but, to give strength, the back is made conical.

In those cases in which the flat face of the tool can be applied to the convex side of a curved recess, no material difficulty is experienced in cutting the outline nearly perpendicular to the surface, as the stone can be slowly, but continuously, twisted round to bring every successive part of the curve in a direct line with the flat face of the tool, and should

the edge of the outline be irregularly cut at the first attempt, a second cut may be taken with a smaller tool in the same manner but so as to correct these irregularities, and during the entire process the tool and work remain constantly under observation. But it will be readily conceived that the flat face of the tool cannot be so conveniently applied to the concave side of the recess, as the edges would have a continual tendency to encroach upon the curved line and, therefore, in cutting around the concave side of a curve the conical back of the tool must be made to traverse around the inside of the curve; but the back of the tool being less under observation than the face, it is much more difficult to cut the edge smoothly, and in any attempts to correct the irregularities with a smaller tool it is necessary to adopt the same course of applying the back of the tool to the concave edge of the work, as it is found that when the edge has been cut with the back of the tool, the face cannot be successfully applied to rectify any minute errors.

The difficulty of making a sunken surface quite flat, arises from the circumstance that the entire face has to be produced with only a very small portion of the edge of the tool, and without any mechanical guidance being derived from the tool itself. For although the edge of a tool, such as fig. 373, may be turned very nearly flat, yet on examination after being used it will always be found rather convex, because the edge has a constant tendency to wear the fastest at the margins, and the rounded edge of the tool has naturally a continual tendency to cut the surfaces to which it is applied into a series of small hollows instead of one continuous plane. In flattening a sunken surface, or, as it is sometimes called, *stippling*, the difficulty is overcome by keeping the stone in continual but steady motion. The stone being quickly traversed with very short strokes beneath the tool, the entire surface is successively passed under the lowest point of its circumference, which is only allowed to cut at the highest points of the surface, and these are determined apparently by intuition, so delicate is the sense of touch acquired by the best gem engravers; but, as may be imagined, this great dexterity of hand is only to be acquired by long and patient practice.

When the stone requires to be much inclined from the per-

pendicular, to allow small tools to penetrate into the minute details of deep works, the difficulties are materially increased. As previously mentioned, some of the little discs are less than one hundredth of an inch in diameter, while, to afford sufficient stiffness to the tool, the diameter of the stem requires to be about one-eighth of an inch at the back, and the front end is made conical for about 1 inch of its length from the disc, as seen in the greatly enlarged section, fig. 378. To enable these small tools even to penetrate into a flat surface, it is obvious that the stone must be inclined to a greater angle than the cone of the stem, or the latter would rub on the flat surface; but in finishing a deep corner, so as to make it quite square and sharp at the bottom, the stone must be inclined to a much greater angle and, in consequence, instead of the tool cutting perpendicularly downwards, it cuts obliquely, at the same angle as that at which the stick is held, and this tendency of the tool requires to be overcome by the tact of the artist. In the case of squaring a corner, there is generally sufficient room in the sunken portion to allow the entire disc to be inserted within the cavity upon the side of which it is principally required to operate, and the surface of the stone may be held nearly vertically. But in cutting fine lines on a deep surface, such as some of the finishing lines in the hair of a deeply sunk head, these do not admit of being made much wider than the edge of the tool. Very delicate management is required to sink these lines perpendicularly to the general surface, and the stone must be applied to the tool so as to commence the cut a little above the exact position for the center of the line, in order that the oblique cut, when made to the appropriate depth, may terminate in the desired position.

In ordinary seal engraving great accuracy of finish in the details is never attempted, and these difficulties of manipulation are not severely felt, but they are a great obstacle to the practice of the higher department of gem sculpture, which not only requires the artist to possess great talent for the conception of beauty both in form and design, but he must also devote many years to the attainment of sufficient mechanical dexterity to enable him to realise his conceptions in detail. The gem engraver also labours under the further disadvantage that, from the minute and delicate character of his

works, they can only be properly appreciated by those few persons who have carefully studied the subject. It is also very generally supposed that the ancients greatly excelled the moderns in gem engraving, and that the art has never been carried to the highest perfection in this country. Mr. Henry Weigall, however, has said, "this supposition is erroneous, and has probably arisen from the fact of travellers supposing that the collections of gems and impressions that they have made in Italy, are exclusively the works of Italian artists; such, however, is not the case, and I have myself had the satisfaction of pointing out to many collectors, that the most admired specimens in their collections were the works of English artists. Selections may be made from the works of Wray, Burch, Marchant, and Charles Weigall, which will bear comparison with the finest works that have been produced in any age or country." Mr. Weigall has omitted the mention of his own performances, but the reputation his works have acquired in this and other countries more than justifies the insertion of his name in the above list of artists.

The engraved surfaces of ordinary works, such as armorial bearings, are commonly left from the cutting tools and are not afterwards polished; but in superior specimens of gem engraving, when it is desired to give the work the highest possible finish, the engraved surfaces are all polished in the most careful manner. For this purpose the surfaces are first smoothed with copper tools, made of the same shapes as the finishing tools used in engraving and charged in the same manner with diamond powder and oil; but the diamond powder is ground finer than that used in engraving, and the copper tools being softer than those of iron, the particles of diamond become more deeply embedded in their surfaces, and therefore leave a much smoother result. After all the engraved surfaces have been smoothed with copper tools, similar tools made of boxwood, charged with still finer diamond powder, are employed to complete the smoothing. The boxwood tools cut very smoothly and leave almost a semi-polish, which is completed with copper tools, charged with rottenstone and water.

The process of polishing minute works with much detail is however, very tedious, as every one of the markings requires

to be operated upon separately, and the process demands much skill and attention not only to exactly re-enter each line, but also to prevent the sharpness and delicacy of the engraving from being deteriorated. To economise time in polishing common works where precision of form in the details is not considered of importance, scratch brushes are sometimes employed; these are made of fine copper wire fixed in the end of a tool, and sometimes bent up at right angles to the axis to make a small wheel brush, which is charged in like manner with rottenstone and water. This practice is barbarous in its destruction of delicacy of form and line, and is mentioned only for depreciation.

The process of seal engraving is applied to all gems inferior in hardness to the diamond, and even this latter has been engraved in some rare instances. The sapphire cuts very slowly but smoothly; the ruby cuts slowly, but small pieces are liable to break off in flakes; carnelian and bloodstone are close in their structure, and admit of being cut with very smooth surfaces; and the emerald cuts as readily as bloodstone. Softer stones admit of being cut more rapidly, but do not when finished present such smooth surfaces as the harder and more compact materials. The amethyst is, perhaps, as soft a stone as can be cut very smoothly, nevertheless, glass and even marble are sometimes successfully treated by the seal engraver, but the tools soon become deteriorated, owing to the diamond powder becoming embedded in these soft materials. When the stones consist of layers of different degrees of hardness, increased caution is required to prevent the tool penetrating more deeply at the softer parts. An onyx engraved in intaglio, so that the device is seen from the surface in the colours of the lower stratum, is called a *nicolei*.

Engraved diamonds are exceedingly rare, and as to most claimed to be such, it is a moot point with experts whether the stones are diamonds or clear white sapphires. One authentic example is the diamond signet of Henrietta Maria, consort of Charles the 1st, which gem was eventually acquired by Mr. Drury Fortnum, F.S.A., and presented by him to H.M. Queen Victoria in March, 1887; it is not known by whom this diamond was engraved. Engraving the diamond adds nothing but rather detracts from the beauty of the gem, the most it

gives is a fictitious value from the rarity, extreme difficulty and cost of the work, and from these points of view the following and, so far as the writer can ascertain, unique modern example, is of interest. Messrs. Renton and Warner of London, in 1884, agreed to engrave a diamond signet for the use of the King of Siam, and the stone provided them proved to be a layer split off a hard Indian diamond, about a sixteenth of an inch thick by nearly half an inch in diameter, which had been already ground and polished parallel and circular and cut with small triangular facets around the margins of both surfaces. The ordinary process of engraving entirely failed, as throughout many persevering attempts the little tools invariably slipped on the hard polished surface of the diamond and refused to penetrate, neither were they more successful when the polish had been removed ; the engraving, therefore, could not be effected until some mode was discovered by which the one could be kept in contact with the other. The following ingenious expedient was finally adopted, the stone was painted all over with a spirit varnish, covered with black lead and then coated by electrotyping with a thin layer of copper upon which the design was marked, and the copper coated stone cemented on the stick. This proved completely successful, the tools readily cut through the copper the edges of which held them in position and thus allowed them to penetrate the surface of the diamond, and there remained then only the dextrous manipulation to avoid enlarging the width of the lines cut through the copper and the long tedious labour of sinking them in the stone. Numerous particulars were collected throughout, among them it may be mentioned that the strokes and curves of the Siamese cypher engraved, taken as a continuous line, measured just 1⅛ inch long, they were cut to an inconsiderable depth and the material removed reduced the original weight of the stone only one forty-second part of a carat. On the other hand the removal of this small quantity required an expenditure of 3½ carats of diamond powder, or 147 times its weight, and eighty-six hours sustained labour. An exact copy of the engraving made in rock crystal was executed in less than half an hour and required only the one-hundredth part of a carat of diamond powder, or less than half the weight of the material removed. The diamond when

polished after it had been engraved proved to be more than usually hard, it was placed in the hands of Messrs. Ford of Clerkenwell for this purpose, and the polishing required twice the time usually occupied upon a stone of its dimensions.

The very excellent proof impressions taken in wax by the seal engravers, are produced in the following manner. The stone is first thoroughly cleaned with a moderately soft brush, it is then warmed over the flame of a candle, the stone being traversed in a circle at a moderate distance above the flame, that it may be heated uniformly. If the stone were held stationary above the flame it would be liable to be cracked, from one portion being heated more rapidly than another. The usual test for the proper degree of heat is the placing of the seal upon the naked hand, and if the heat be about as great as can be borne by a tolerably sensitive hand without causing pain, it is considered to be suitable. The intaglio of the seal is then coated with a very thin layer of clean tallow, applied with a small brush, such as a rather soft nail brush, and the tallowed surface is again coated with a thin layer of vermilion, applied with a camel's hair pencil. This completes the preparation of the seal, and when the impression is made, the vermilion becomes attached to the surface of the wax, and materially heightens the beauty of the impression.

The sealing-wax is prepared by holding the stick of wax at a little distance above the flame of the candle, until it is thoroughly softened, but it is only so far heated as is necessary to allow of a sufficient quantity of wax being detached to form the impression, and care is taken to avoid blackening the wax, either by smoke, or by allowing it to become ignited. The softened wax is deposited in a small heap upon a piece of stout paper, and when enough to form the impression has been placed on the latter, the fusion of the wax is completed by traversing the under surface of the paper above the flame of the candle, but at a sufficient distance to avoid scorching it. When the wax has become thoroughly softened, it is stirred with a small stick to drive out all the air bubbles and work it into a uniform mass of a conical shape; the paper is then laid upon the table, and when the surface of the wax has become bright and

quiescent, the seal is applied to give the impression. In order that both the seal and wax may be at the requisite temperatures, the preparation of the two is carried on almost simultaneously, and usually the seal is held over the flame of the candle for a few seconds to restore the heat, while the wax is assuming the quiescent state.

In applying the seal to the wax, its handle is held between the thumb and the first two fingers, applied as near to the seal as convenient. To give steadiness to the hand the wrist is rested upon the surface of the table, and the position having been carefully determined, the seal is quickly dabbed upon the wax with a firm perpendicular stroke but with only moderate force. Some little practice is necessary to attain sufficient dexterity to give the impression with precision; but the method of quickly dabbing the seal upon the wax yields far more defined impressions than the mode sometimes adopted of applying the seal with quiet but considerable pressure, which not only fails to copy the most delicate of the lines and angles, but the imperfect copy thus produced is also liable to be further deteriorated by the seal sliding on the gradually yielding wax, which then receives a double impression. In this, as in similar processes, the most sharply defined impressions are produced by employing sufficient momentum to drive the wax at the same instant into all the minute crevices of the seal, exactly as in the clichée casting and type founding, alluded to at page 324, Vol. I.

SECTION II.—CAMEO CUTTING.

Cameo cutting, or the engraving of gems in relief, is effected with the same apparatus and by the same general methods as those employed in engraving corresponding forms in intaglio, and both arts are occasionally practised by the same individuals. The principal differences in the manipulation of the seal engraver and the cameo cutter arise from the design being in the former case wrought concave, and in the latter convex. The tools with which the former are produced, being themselves convex, they may in most cases be selected of counterpart curvatures to the concave details required in intaglio engraving; but the convex forms in cameo cutting have also

to be produced with convex tools, which cannot therefore be selected of counterpart forms, and the convex surfaces have to be wrought by twisting the stone about at all angles beneath the rounded edge of the tool. For this reason the engraving of gems in relief, is sometimes considered to be more difficult than engraving in intaglio. On the other hand, however, the deep recesses in cameos are generally more accessible than those in intaglio, and the principal source of difficulty in gem engraving is therefore in some measure avoided.

The stones selected for cameos, are generally those called onyxes consisting of two layers of different colours forming a strong contrast, such as the black and white layers of the agate, or the red and white layers of the carnelian. The design is almost always engraved exclusively in the white layer, and the dark coloured layer forms the background, the contrast of the two serving to render the figure more distinct. Sometimes onyx stones having three or more layers of colours are employed for cameos, these are selected when either from the great amount of relief desired in the engraving, the thickness of the white layer would be insufficient to allow of the entire design being engraved in it, or when it is desired to make the most prominent parts of the work of different colours in order to improve the effect.

Mineralogists generally restrict the name *onyx* to a variety of chalcedony, consisting of alternate layers of brown and opaque white, but those artists who work in precious stones usually attach a much more extended signification to the name, and the following interesting particulars from the pen of Mr. H. Weigall will explain the cause of these discrepancies. "All the stones in different coloured layers employed for cameos, are known to *practical men* by the general name of onyxes; but some confusion has arisen with regard to the nomenclature of stones of this class, in consequence of the imperfect information of those authors who have undertaken to describe them. It is a remarkable fact that no author who has undertaken to describe the onyx, has given this simple, intelligible, description of it, namely, a stratified stone occurring in any of the semi-transparent or opaque varieties; thus there is the onyx of the sard, called the sardonyx, that of the carnelian called the carnelian onyx, and so on through the

whole variety of stones. The name onyx is derived from a Greek word which signifies nail, and the authors before referred to, have evidently been perplexed to make out any resemblance between such an object and that particular variety of the onyx which they happened to describe. Thus Pliny could see no resemblance to a human nail in the specimen from which he took his description of the onyx (which appears to have been a bad sardonyx), and he therefore thought it must be a horn or hoof, and fancied a resemblance to a horse's hoof. Theophrastus seems to have described a cloudy specimen of the carnelian as the onyx, and he fancies it resembles the pink and white colours sometimes observable on the human nail." Mr. H. Weigall however suggests that there was an original propriety in the name, and that it most probably arose from the practice of staining the nails, for if the stain were only applied at distant intervals of time, the lower portion of the nail would grow between the applications, and present a band of white at the bottom of the coloured nail and thus render it a fair type of the onyx stone.

The stones to be cut into cameos are prepared by the lapidary, and to avoid wasting the material each stone is left as large as possible. The cameo cutter has therefore to select a stone as nearly as he can in accordance with his intended design, which must be afterwards modified in some degree to suit the stone.

As a preliminary to cutting the cameo, it is most important that the artist should have a clear conception both of the design and of the capabilities of the stone. To assist in this, he first makes a sketch of the design on an enlarged scale, and then having considered the degree of relief that will be adapted to the thickness of the white layer, he makes a model in wax of the exact size of the stone. With unimportant works this is frequently omitted by practised artists, who depend upon their skill for overcoming any difficulties that may arise, but it is at all times a great assistance in elaborate works. The model and stone are carefully compared, and any alterations that may be demanded by the formation of the stone, are then made in the model.

When the stone is in three layers, additional care is required to adapt the design to the stone. It is at all times desirable that the line of division between the colours of the two layers forming the ground and figure should be distinctly defined, but it is sometimes an advantage when the transition between the two colours in the upper layers is more gradual. For instance, in cutting the head of a Medusa in a carnelian having one layer of white between two of red, if the lines of division between both the layers of red and the white are sharply defined, the features may be cut entirely out of the white layer, and the upper layer of red may be reserved for the snakes, but if the transition between the upper layer of red and the white be gradual, a faint tinge of colour might be left on the cheek with great advantage to the effect, and the skilful engraver of cameos will thus avail himself of every opportunity for heightening the effect that is offered by the formation of the stone. When the stone consists of several layers of colour, considerable scope is afforded for the exercise of judgment in selecting a design in which the whole of the colours can be rendered available.

When the design has been accommodated to the stone as nearly as possible, the outline is sketched on the surface, and cut in with a knife-edged tool, and the superabundant portions of the white layer beyond the outline are removed down to the dark layer forming the ground. The general contour of the figure is next formed, and this is followed by the principal details which are sketched and cut in succession, care being taken to preserve sufficient material at the most prominent parts, and to advance the engraving uniformly, so that the general effect may be compared, from time to time, with that of the wax model.

The surface of the background is conveniently flattened with the broad flat surface of a tool such as fig. 372, and the difficulty of removing the little irregularities on the rounded surfaces of the figure with the convex edge of a revolving tool, may be entirely avoided by the use of a tool called a *spade*, consisting of a piece of soft iron wire about 3 or 4 inches long, the end of which is filed at an angle of 45 degrees, and charged with diamond powder. The spade is held in the fingers like a pencil and rubbed with short strokes, either straight or circular,

to reduce the irregularities of the surface. The last delicate touches are executed with the very small revolving tools, and the cameo is finally smoothed and polished in the same manner as the best works in intaglio.

Cameo-cut glass is produced after the same general method, and with the larger revolving tools of the gem engraver, and the smaller of the glass engraver; an effective, if inferior, imitation has lately been introduced.

The material for cameo glass cutting has a nucleous of delicately tinted opaque glass, coated with one or more layers of similar glass of contrasting colours fused upon it, and is therefore stratified like an onyx. The designs, flowers, tendrils, arabesques, classical borders and figures, of Wedgwood character but often still more exquisitely wrought, are sketched and first sunk down to the ground and square all around their outlines; the design and the ground are then completed more or less concurrently, and are usually left unpolished from the emery fed tools. The upper layers of the glass have to be all cut away down to one level or colour everywhere between and in the interstices of the design, hence, when the work is executed on a vase or other round object there is the additional difficulty of maintaining the perfect circularity of the solid, nevertheless always successfully done.

The imitation cameo glass is produced by a simple process, supplemented by artistic talent, borrowed from that for matted glass. The object blown of its finished form in coloured glass, has the design painted on it by hand in a mixture of the constituents of opaque glass and, when dry, the two are fused together. Single touches are used for foliage and tracery, and many repetitions built up in impasto for higher relief, as in figures, the modelling of which last is often of great merit; the materials adhere well to one another, and the decorations on these imitations are not easily damaged.

The method of *carving* cameos in conch shell, described in the Catalogue under Shells, article 8, is more expeditious, and presents much less difficulty than the engraving of cameos on gems, but the shell cameos do not admit of the delicate cutting and elaborate finish usually bestowed on true cameos, and they are also much less durable.

SECTION III.—GLASS ENGRAVING.

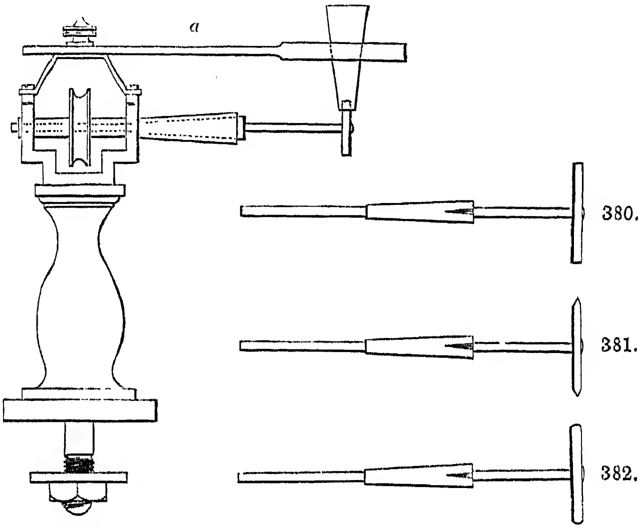
Engraving on glass is executed in much the same manner a seal engraving and with tools of similar forms, but the designs on glass works are usually of larger dimensions than those on gems, and the tools are therefore of proportionately greater diameter. In order to permit large objects, such as decanters or squares of glass, to be applied to the cutting wheels, the latter are fixed on stems that project from six to ten inches from the front of the lathe head, or as it is generally called, the *tool*. The wheels employed are made of copper, and charged with fine flour emery and oil. When the engraved surfaces are required to be polished, similar wheels made of lead are used, charged with pumice stone powder and water.

The glass engraver's tool shown in fig. 379, like the engine used by the seal engraver, is mounted upon a stout bench about 2 feet 6 inches high, and driven by a treadle and foot wheel, from 18 to 24 inches diameter. The metal frame that carries the mandrel is supported upon a wooden pillar, called the *stock*, which is generally of such a height as to place the center of the mandrel about 10 inches above the surface of the bench, in order to allow sufficient room for applying the objects to be engraved to the lower edges of the wheels.

For works of ordinary sizes, the mandrel is made about 8 inches long, and is supported at the left hand end in bearings, about 4 inches asunder. The remaining portion of the mandrel projects from the front of the tool, for the purpose of receiving the spindles of the wheels, which are made, as shown in figs. 380, 382, with a conical plug cast on a central wire about 10 inches long, and the copper wheels which vary in size, from about one-eighth of an inch to 4 inches diameter, are screwed or rivetted on the ends of the wires.

The overhanging portion of the mandrel has a conical hole, measuring about half an inch diameter, at the larger end, and one quarter of an inch at the smaller, for the reception of the leaden plug on the spindle of the wheel, which is cast either in the cavity of the mandrel itself, or in a mould of corresponding form, made like that of the seal engraver, shown in fig. 369, and having in like manner a nick in one side, to form a

feather, that fits into a similar nick in the mandrel. In the tool shown in position, fig. 379, a small cylindrical hole extends from the bottom of the conical hole to the back end of the mandrel to allow of the passage of the spindle, which projects slightly beyond the end of the mandrel, in order that the plug may be loosened, by gently tapping the end of the spindle. More generally, however, the spindle does not extend throughout the length of the mandrel, but a transverse mortise



Figs. 379

is made through the latter, just behind the front bearing, and the spindle is made of only sufficient length to extend partly across the mortise and in this case the spindle is released by inserting a lever or wedge. Several other unimportant variations occasionally occur in the construction of the apparatus, which is sometimes made of a much larger size, in order to carry wheels of 8 or 10 inches diameter, but these large wheels are principally required for common works, such as glass globes, and the process then more nearly resembles glass cutting.

The edges of the wheels employed in glass engraving, like those used by the seal engraver, are made in a great variety of forms, but are mostly square, angular, or rounded, and their thicknesses vary from about one quarter of an inch to a knife edge; but from the large diameter of the wheels mostly

used and the comparative shallowness of the engraving, it is not generally necessary to incline the surface to be engraved in order to avoid the spindles; and therefore the edges of the wheels used for flat surfaces are made cylindrical, as shown in fig. 380, instead of being conical as in the corresponding tool for seal engraving, seen in fig. 373.

For very minute works in glass engraving, however, such as are met with in small figures of animals, architectural views, or landscapes, wheels not exceeding about the fiftieth of an inch in diameter are required. The edges of these small wheels are formed exactly like the tools of the seal engraver, and in like manner are made of carefully annealed iron wire, first roughly filed into form and then carefully turned down to the required sizes with the graver. But, as previously intimated, glass is too soft a material to be smoothly engraved with iron wheels; iron is therefore only employed for those wheels that are too small to be made as copper discs attached to iron stems.

In charging the wheels, fine washed flour emery is mixed with olive oil, in a small shallow saucer, which is frequently applied to the lower edge of the revolving tool. The lead wheels for polishing are charged in a similar manner, with pumice stone powder mixed with water. To prevent the wet powders from being thrown against the person of the artist by the centrifugal force, a light radial arm is attached by a screw to a cap mounted on the mandrel frame, as seen at *a*. The arm is made of sufficient length to extend a little beyond the edge of the wheel, and has near the end a long slit, cut at a few degrees from the perpendicular, through which is passed a thin strip of metal, or wood, about one inch wide, and tapered at its lower end, which is adjusted for height, so as to stand in front of and towards the upper edge of the wheel.

Glass engraving is principally applied to the smooth surfaces left by the glass blower, but sometimes for greater elaboration, the works are prepared by the glass cutter, but whether the general surface be greyed, or polished, the engraving is not commenced until the object, such as a decanter or wine glass, is completed in all other respects. The glass engraver first sketches the general outline of the design with a pen and ink, or more generally with some fine powder, such as powdered

chalk, mixed with a little gum water. The engravings on glass being mostly shallow, do not require to have the outlines deeply cut, as in seal engraving, and all broad surfaces are at once produced with large tools having flat or rounded edges, which are applied first to the center of the surface, and this is gradually enlarged until it reaches the outline. The secondary parts of the design are then sketched, and cut in like manner with smaller tools, and as the minute details are approached, smaller and thinner tools are employed, just as in seal engraving. When the designs are simple and do not require great exactness, the general outline alone is sketched, and even this is in some cases omitted when the same design has been frequently repeated, but where great precision is required all the details are sketched and cut in succession.

In applying the object to the wheels, it is grasped in both hands and held against the lower edge of the tools, moderate pressure is required to cause the larger tools to penetrate, but the small tools require very little. The arms are steadied by resting each elbow upon a leather cushion, but the large sizes of the works do not allow of the hand being rested against the lathe as in seal engraving. The designs are also larger, and require greater freedom of motion in the hands, the weight of large objects, such as decanters, also increases the difficulty. The execution of small and highly finished designs, therefore, requires great delicacy of touch and much practice, but notwithstanding these difficulties, very beautiful specimens of the art are constantly produced.

In those specimens in which the general surface of the glass remains as it left the hands of the glass blower, or when it has been subsequently polished, the engraving is generally left grey from the emery charged tools, but when the surface of the glass is greyed or ground, some or all parts of the design engraved upon it are more usually polished for the advantage of the contrast. The two methods are also frequently combined, thus in engraving such a design as the monogram fig. 383, upon the clear blown glass bowl of a wine glass, the letters would be engraved to one uniform depth over every part of their widths and left grey and, subsequently, lines all around the margins and crossings of the letters and the dots would be engraved to a second depth and polished. Beautiful

effects are also engraved upon glass in two colours, in which the body of the object is blown in white flint glass that is coated with a thin film of coloured glass; the design whether left grey or partially polished is then developed by engraving entirely through the coloured glass to leave the pattern clear white, or the coloured glass is left to form the design and the portions around are removed to leave that upon a white field. In some more elaborate engraving the design is worked in a thicker coating of the coloured glass, and the effects of light and shade are produced by leaving the coloured coat of its full thickness for the deepest shade and cutting partially or entirely through it for the lighter and the highest lights. The production of work of a similar character but on a coarser scale upon coloured faced sheet glass by the sand blast has been already described in a previous chapter.

SECTION IV.—GLASS ETCHING.

Glass etching upon table ware and decorative objects produces the design in a small depth of intaglio, which is either clear and transparent, almost as if cut and polished, or slightly frosted and translucent, or, still greyer and somewhat approaching the colour of ground glass and opaque, according to the duration of the process by which it is effected; etching of these three characters is placed upon clear white or coloured glass and upon ground glass in the following varieties, viz., clear bright intaglio upon fields of bright white, on semi-frosted, on ground, and upon coloured glass, and semi-frosted and grey intaglios upon bright white, semi-frosted, and coloured fields.

The process consists in first entirely covering the glass with a tenacious greasy medium, or with an analogous varnish, through which the pattern is scratched with a steel point, and then biting in the design thus exposed by subjecting the work for a longer or shorter period to the fumes of fluoric acid, which yields the grey varieties; or by immersing the partially protected object in hydrofluoric acid in a leaden bath for a period of from five minutes to one hour, according to the strength of the acid and the depth of the intaglio required, which gives the translucent semi-frosted etching; and for the

brilliant transparent variety, by a similar immersion in a mixture of hydrofluoric and sulphuric acids.

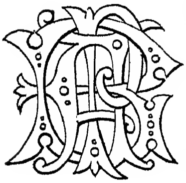
In the translucent etching most commonly met with, the bottles and glasses are decorated with bands of contiguous or overlapping circles, bands of the Grecian or so-called key borders, or bands of other zigzag lines, and plain concentric lines, slightly sunk below the bright surface of the glass; which patterns, produced on vast quantities of work, are scratched through the protecting medium in machines. The higher class and more artistic etching, floral designs, arabesques, &c., are drawn and scratched through with the point by hand, and in these the design is sometimes heightened in effect by subsequent partial engraving, cutting and polishing, wrought upon the surfaces and around the margins of the etching. In a further variety the entire ground of the object is first reduced to the translucent semi-frosted condition in the acid bath, then washed, dried and coated with the resisting medium through which the pattern for the bright or translucent etching is drawn; and in another and bolder variety, the design is traced everywhere around its outlines through the medium, the latter is next carefully cleared away from between all its interstices, and the ground is then uniformly and deeply eaten away, bright, by a more protracted immersion of from one to three hours; the design left in full relief by this broader and more vigorous etching is then cut, polished or engraved and also sometimes further etched, often to great elaboration.

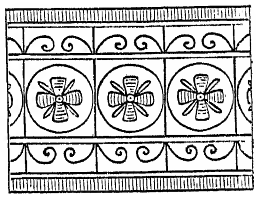
The film used to protect the glass is composed of purified beeswax mixed with clean tallow and a small proportion of resin, and its uniform thickness in deposit is obtained, in most cases, by dipping the heated glass in the melted mixture and then allowing it to drain. When cold and set the film must absolutely adhere to the glass to prevent the acid from penetrating beneath its scratched edges, it must also be sufficiently tenacious in its substance not to crack and to leave clean sharp edges from the needle and yet to be readily removed by the latter; the materials used perfectly meet these rather opposing conditions, but require some slight variation in their proportions according to the temperature of the season and workshop. Notwithstanding the semi-soft con-

dition of the film the etcher succeeds in drawing the most elaborate designs through it, and in removing all particles required, with the point alone, from all over a heavy decanter or jug held in his other hand, without damage to the integrity of the remainder of its surface; during which operations he supports the wrist of his right hand upon a horizontal rest or bar, similar to that used by the painters on china, holding the glass in the left, firmly pressed against the edge of the table beyond and above which the rest projects.

The linear patterns on the etched glass first mentioned, are

Figs. 383. 384. 385.





traced with great rapidity in light machines which possess many of the powers of the lathe for ornamental turning. For ornaments composed of bands of circles, the beeswaxed wine glass or decanter is mounted in the machine to revolve upon its axis horizontally between centers, and is arrested from point to point in its rotation by a worm wheel and tangent screw, the latter under variable control as the circles to be scribed are required to be separated, contiguous or to overlap. The scribing point, a thick needle with a blunt rounded end, is applied at right angles to the axis of the glass and is mounted in a short cylinder that fits within a corresponding socket in the holder on the slide of a light form of the eccentric cutting frame, fig. 193, Vol. V., so that the needle may be placed centrally to revolve upon itself to mark a dot or, by the traverse of the slide, to any radius from that of the smallest to that of the largest circles to be scratched. The spindle of this eccentric cutting or scribing frame revolves with its axis in the plane of that of the glass, mounted on a slide by which

it is pushed forwards towards the glass and then withdrawn by the hand for every circle traced; but in addition, a spiral spring in the socket behind the cylinder also pushes the needle forward independently, so that the latter compelled by the cylindrical superficies of the glass with which it is in contact, yields or advances by the pressure of the spring and removes the film equally throughout the entire circumference of each circle it scribes, notwithstanding the convexity of the form upon which it is operating. The pattern resulting from any adjustment of the machine is repeated on a large number of glasses, and when these latter have to carry more than one band of ornament the machine is then readjusted and the glasses are remounted in it seriatim to receive this second, and so on if for more. The plain concentric lines frequently placed above and below to edge the bands of circles, as in fig. 385, are struck around the glass with a plain spring point, the glass rotated in the machine by the hand; and for ornament composed of continuous zigzag or other lines, this last named needleholder is reciprocated laterally upon a slide parallel with the axis of the work under the control of various adjustable guides, sometimes of a rose-engine character, which are put in revolution and connected with the rotation of the mandrel that carries the work by a train of wheels to give each their appropriate rate of movement; the spring to the needle causing that to independently advance and recede to maintain its contact with the cylindrical or tapering form of the glass as before.

The illustrations figs. 383-385, which are about the natural size, in some degree indicate the character of the more artistic etching produced by hand. The spray of foliage and flowers, fig. 384, is scratched through the beeswax with a round ended needle about one fortieth of an inch diameter, fixed in a penholder form of handle about the size of a cedar pencil. The looped grooves forming the design are all of uniform depth and width, and the immersion in the fluoric and sulphuric acid is prolonged sufficiently to cause their depth to rather exceed their width; they are also all rounded at the bottom, which appears to arise partly from the grooves in the wax being themselves rounded from the end of the needle, and partly from the more perfect protection from the acid

given by the sides of the wax grooves in all long immersions. All these little curved sunk furrows are clear and bright, but they nevertheless display the design brilliantly in contrast to the bright polished surface of the white glass upon which they are placed, from the one side of every groove being in shadow and the other catching and reflecting the light, an effect increased and diversified by the differing extent to which they receive illumination from their standing at all varieties of angles to one another. Five of these sprays are placed around a claret glass, and it is notable as an example of the manual dexterity achieved by great practice that, not only are they equally spaced out around the glass, but there is no perceptible difference in the dimensions or execution of any one of them. The monogram fig. 383, opaque upon a bright ground, also executed by Messrs. Osler at Birmingham, has had the letters first etched to a slight uniform depth, after which they have been re-etched to an increased depth with lines around their margins and crossings, and the dots subsequently engraved and polished. The wine glass border, fig. 385, has had its circles and concentric lines scribed around the glass by the machine and the remaining portions of the design executed by hand; this pattern offers a further variety, inasmuch as the lines are drawn with points and needles of different diameters, some of them with comparatively broad ends, but all were bitten in grey to one depth.

Some beautiful delicate ornamentation in small tendrils and foliage, arabesques and other designs, is produced by first subjecting the entire surface of the glass to the acid vapour until it becomes semi-frosted and translucent, and then stopping out all portions of this surface required for the ground with the resisting medium, applied by transferring, printing or painting, so as to leave the pattern only exposed, which latter is then deeply bitten in either grey and translucent by a more prolonged exposure to the acid vapour, or bright and transparent by immersion. The production is a more careful carrying out, upon a small scale, of one of the processes followed for the decoration of sheet glass, already described, rather than etching, as the needle is not employed.

CHAPTER XII.

DIAMONDS AS ABRASIVE AND CUTTING TOOLS.

SECT. I.—DRILLING AND BORING.

This hardest of all natural substances has long been employed for drilling or, more correctly speaking, for grinding out holes in diamonds and in other stones and materials less hard than itself, but upon which all other tools are inoperative.

The small holes in the gems to receive the pivots in watches are bored with minute splinters of the gem diamond, themselves often first ground or turned to a tapering form with other diamonds, mounted in the ends of brass or steel wires, which drills are shown and their action explained in the first volume. Precisely similar drills, many much more minute, are used in the preparation of the holes in the little discs of sapphire or sometimes of diamonds, inlaid in steel plates for the jewel holes of drawplates for drawing the finest gold and silver wires, for copper and filaments for electrical purposes; the smallest of these holes are but the two-thousandths of an inch diameter, increasing thence with marvellous accuracy by ten-thousandths of an inch upwards, further particulars of which are given in the Catalogue under the head of Sapphire, article 3. The little disc of sapphire or diamond revolving in the lathe is bored from either face with an hour-glass shaped aperture, the point of the diamond tool barely allowed to penetrate from the one cone to the other, and the hole formed by the meeting of the two is then perfected and ground out to size and polished with delicate steel wires fed with the most finely crushed, ground and washed diamond powder and oil; the diamond drills and steel wires are mounted in the ends of brass wires and are applied by hand.

Holes from a sixteenth to about an eighth of an inch diameter, large in comparison with those just considered, are ground out with fragments of the gem diamond of the tri

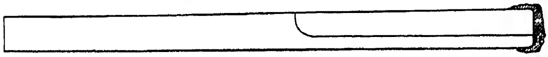
angular shape, figs. 68, 69, Vol. I., in many intractable materials upon which hardened steel drills are powerless. The morsel of the gem is mounted in a transverse notch in the end of a stem of brass or steel wire, within which it is retained by pinching and punching in the edges of the metal around it and filling all the interstices with spelter solder, but so as to leave the point and the two corners at the base of the stone exposed and projecting. Larger holes are readily ground out by the lapidaries and others with the annular faces of short soft steel tubes, mounted on the end of the drill shaft or in the lathe and fed with diamond powder and brick oil or paraffine. The stem of the drill is sometimes mounted and driven vertically in a machine and, it may be mentioned, that similar brass tubes fed with emery and oil are employed for grinding apertures in glass, stone, &c., the material in all these cases being removed as a disc or cylinder.

The fragments of the gem mounted as described will withstand considerable usage when carefully employed, but after a time their angles rub *bright* or smooth and then they are comparatively inoperative; from their brittle nature they are also easily damaged by accidents, and they are difficult to mount securely in their settings, which latter wear away rather rapidly and the diamond may be lost, hence the use of the gem for drilling is generally limited to small holes. Most of these objections have been removed by the almost recent discovery of the harder and more robust carbonate variety of the diamond, see CATALOGUE, article DIAMOND; this material always remains *grey*, in other words does not lose the angles of its fracture from protracted use and it is almost impossible to break it by accidents, it is therefore generally preferred to the bort or fragments of the gem for all but the very smallest holes; it is mounted after the same manner and sometimes for boring holes less than the one sixteenth of an inch diameter, and is employed for all the larger boring tools and for most of the other tools referred to in this chapter.

An irregularly flat piece of carbonate left from its natural amorphous fracture was used in the drill, figs. 386-7, made by the writer to bore axial holes, one quarter of an inch diameter and one inch deep, in some electrical carbon rods of an exceptionally hard character which instantly turned the edge of

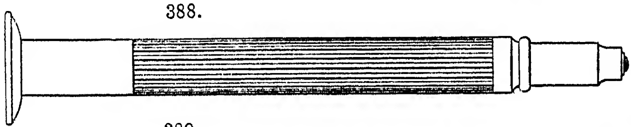
the hardest steel drills. The general form of this drill follows that of one of the small drills lately mentioned, and it had the carbonate held within a jagged notch cut across the end of a slightly tapering steel stem of rather less diameter than that of the hole to be bored. In fixing the one in the other the stone was first moderately pinched between the sides of the notch and, after the stem had been made to run true in the lathe, it was adjusted laterally until one of its projecting side corners described a circle of exactly a quarter of an inch

Figs. 386.

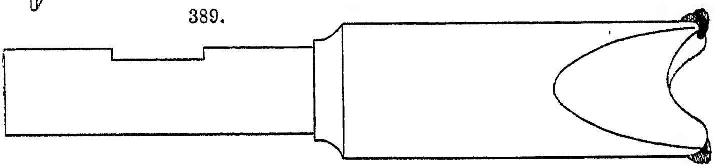


387.

388.



389.



diameter; this was followed by further hammering the steel well down on the rough sides of the stone and carefully filling in with spelter solder and, finally, a flat was filed on each side of the stem on which the corners of the stone projected to give additional clearance for the escape of the powder formed in boring; the whole stone was left irregular at its natural fracture. In use the drill was driven rapidly in the lathe and the carbon, clamped down in the tool holder of the sliderest, was advanced to it at a gentle pace by the main screw of ten threads to the inch of the latter; the drill bored out the holes dry, perfectly smooth and true, completing each in about one minute.

Smaller carbonate diamond drills for boring holes partially through china for the insertion of the *rivets*, small brass wire staples, used for repairs, are made of steel wire after the manner of fig. 386, but the lateral projections of the stone are a little more in proportion to the size of the stem, which is left round without the flats; they bore holes from a sixteenth

to about a tenth of an inch in diameter. These drills may be conveniently mounted to run true in the lathe and the pieces of china are then pressed against them held in the fingers. By the working china-mender they are placed in the stem of an upright drillstock with a cross staff, fig. 4, Vol. IV., sometimes in the end of a stem driven by a drillbow, or in an Archimedian drillstock; the piece of china is then held at rest, in the first case, in the one hand of the operator, and in the others, the workman is seated and the piece of china is secured on his knee in the loop of a strap held down by his other foot, or after the same manner on a piece of wood covered with some soft material and projecting from his work-bench. It is always necessary to first remove the glaze from the china at the spot the drill has to enter, this is effected by the little tool, drawn full size, fig. 388, a fragment of ballas bort diamond inserted in the end of a fluted stem, of which the other end is secured and turns in a flat button. The diamond is pressed vertically and hard on the china with the button in the palm whilst the stem is turned by the fingers of the same hand, until the glaze is ground away; in piercing holes in china the carbonate drills are lubricated with paraffine or turpentine.

For some exceptional drills and other tools the carbonate fragments have to be partially shaped before or after they are mounted in their stems, a reduction often convenient with drills similar to fig. 386, when they are required for holes of very accurate dimensions. From its intense hardness any shaping of carbonate is a slow process, a piece is therefore always selected which so far as possible approaches the desired size and form and this is then ground to shape upon another piece of carbonate placed in revolution. Mr. J. Ker Gulland employs the small grinding machine, fig. 52, with a piece of carbonate embedded in a chuck running on its vertical mandrel, the nearly flat surface of the stone, therefore, revolves horizontally.* The fragment to be shaped is pressed down on the

* The piece of carbonate here mentioned is of remarkable size and form, a ragged edged, irregularly square figure, measuring about one and a quarter inches across each way by about five-eighths thick, with one face very nearly flat; it weighs nearly 300 carats, and is of fabulous value. Mr. Gulland has met with only one piece larger which lately reached him from Brazil and weighs about 500 carats, but

revolving carbonate by hand, temporarily clamped in a holder of the character of fig. 392, or when already mounted in its permanent stem; the two stones are constantly well moistened with water which proves superior to any other lubricant. Grinding the one stone on the other usually suffices; but when absolutely flat surfaces are required on the piece ground, these are first prepared on the revolving carbonate and then completed on the iron lap of fig. 52, fed with crushed carbonate diamond powder and oil, a process resorted to only because the face of the revolving carbonate stone although fairly flat is not sufficiently so to produce a true surface.

The larger drills shown by fig. 389, are used with a plentiful supply of water for boring holes to about an inch diameter in marble and granite, held by their tapering stems in the socket spindle of a vertical boring machine. Two fragments of the rough carbonate are embedded opposite one another in the periphery of the solid cylindrical end of the steel drill, and the metal is then filed away to a hollow between them and to tapering flats down either side of the cylinder for the escape of the powdered stone washed out of the hole by the stream of water; besides their permanence in wear, these drills are remarkable for the small size of the pieces of carbonate compared with the work they perform. Holes of larger diameter are more economically bored in stone with tubular or crown drills having four or more carbonates.

The tubular drills may be considered as enlarged copies of the little annular drill, fig. 71, Vol. I., but, following the vast increase in dimensions, with the diamond powder replaced by the diamonds themselves; moreover, as will be gathered from some interesting particulars in the Catalogue, DIAMONDS, article 9, all these drills both large and small are probably survivals or reintroductions of tools previously used in long past ages.

The modern application of the solid diamond mounted in rings or crowns for boring, originated with M. J. Rudolph

does not possess the unusual flat surface which renders the first capable of grinding other stones. It is said there is a third piece in existence weighing 700 carats. The fragments of carbonate used for the drills and tools mentioned in this article are at present worth fifty shillings per carat. Carbonate is usually found in quite small pieces, and these rare large specimens may be said to hold a similar place to it as do the few large historic diamonds with respect to the gem.

Lescot, a French engineer, in 1862, and the system adopted by that gentleman has remained virtually unaltered, all variations in its later and great development having been in such details as the methods of fixing the diamonds, the general substitution of the carbonate for the gem diamond and in the machinery for applying and driving the drills. The first of these drills within the personal observation of the author was made by his firm under the direction of Sir Felix Slade in 1871. The crown consisted of a cylindrical steel ring, three quarters of an inch deep by one and a half and three quarters of an inch external and internal diameters, with a wide deep screwed groove turned in its upper annular surface for its attachment to the end of the tubular boring bar. Gem diamonds the size of small peas, otherwise valueless from flaws or bad colour and in their natural state as found in the gravel, were inserted in holes bored at an angle of 45° through the arrises of the lower face of the ring into the groove, made equidistantly four in the outer and four in the inner edges of the ring; these holes were tapered from behind with the file and each enlarged to the shape of its particular diamond, until all the stones when dropped into their places through the groove had about equal projection and also stood out equally over the surface and cylindrical margins of the ring; the diamonds were finally secured by filling in all the vacant spaces around them and also the groove to a small distance above them with hard brass solder, and by punching in the steel externally against them. Gem diamonds are still used but crown drill boring has attained its present importance, and has been enormously extended since the discovery of the carbonate diamond now generally employed.

Diamond crown drills vary from 2 to 24 inches external diameter, they are driven by powerful machinery to depths which range from 500 for the smallest to over 2000 feet for the largest, and they bore through all stratifications, cutting or grinding their way through granite, conglomerate and the hardest rocks in sinking shafts, in tunnelling and for other rock boring on land or under water. The pieces of carbonate are mounted in the smaller drills and in many of the larger after the manner already described, but the inner and outer edges of the face of the crown are subsequently filed away

between the projecting diamonds to assist clearance, and to give access for a stream of water constantly forced down the boring tube to wash away the detritus; hence, in the smaller drills, used among other purposes for boring prospecting holes, which have eight diamonds, this clearance filing causes the crown to approach the shape of a square with the diamonds projecting from the external corners and internally from the centers of its sides, and they have therefore a close analogy in form and action to the tiny drill used by the china-menders.

In the crowns patented by Mr. Gulland the carbonates are removable, so that a damaged stone may be replaced and one set of *points* can be used in several rings. The stones are fixed in the ends of short slightly tapering steel plugs which are driven into corresponding holes bored in the arrises and over the annular face of the ring, arranged in groups so that the work effected by any one stone overlaps that performed by some other; between every stone the annular face is filed away to allow egress for the water forced down the tube. The plugs are further secured by *caulking* or punching in the edges of the holes around them, and transverse holes are bored in the substance of the crowns across their upper ends to allow a taper steel punch to be driven in when it is required to dislodge them. The largest crown yet made on this system is 23 inches in diameter and carries 56 carbonate diamonds of the total value of five hundred pounds; it has seen much service but its diamonds are still unimpaired, it is driven at the rate of from 40 to 50 revolutions per minute.

The boring process is briefly as follows:—The boring rods are formed of lengths of strong steel tubes, of less diameter than the crown, screwed one on to the other as the hole descends, and the bulk of the material cut through remains within the lower joints of the tube in the form of a cylindrical solid core, of more or less length, still attached by its base to the rock, which has to be broken off from time to time and brought to the surface. To do this a part of the driving machinery is removed from its frame and replaced by hauling tackle and so soon as each length of the tube is raised about a foot above ground, a strong clamp with two arms to rest upon the latter to either side of the bore hole, is fixed on the upper end of the next length beneath it, to sustain all the weight of

the tube in the hole below whilst piece after piece is unscrewed. The crown is then replaced by an *elevator*, a deep steel cylinder with three or four long vertical mortises pierced through its sides filled with corresponding steel arms, their lower ends hinged to the cylinder and their upper extremities terminating in chisel quasi-cutting edges. When the tube is again let down, held by the clamp as each length is screwed on, the upper ends of these arms fall forward within the elevator until lifted by their meeting the core, down the sides of which they pass until the tube arrives at the bottom of the bore hole. On again hauling up the chisel edges bury themselves in the softer and impinge against the harder portions of the core, spirally formed corrugations left by the action of the drill, and when the strain has broken off the core they hold it and bring it to the surface. One of the longest cores thus raised was brought from a depth of many hundred feet in boring for a well at Messrs. Meux's Brewery, London, and was one solid piece 50 ft. long by nearly 12 inches diameter, the bore hole having been made with a crown drill of 15 inches diameter. The materials met with in boring, put in order of hardness by Mr. Gulland, are chalk, chalk marl, gault clay, mottled clay or conglomerate, limestone, new red sandstone, gypsum, old red sandstone, granite and red dolomite.

These vertical diamond drilled holes are frequently made to very considerable depths, there are several which exceed 4,000 ft. and one made in search of coal at Schladeback in Prussia, has accomplished 5,736 ft., or the amazing depth of more than one mile. According to particulars given by Mr. Albert Williams as to this last, the boring was commenced at the solid sandstone, reached by first driving an 11 inch steel tube through some 60 feet of superincumbent sand and marl. The sandstone was then pierced to a depth of 570 ft. by percussion with a cast-iron drop drill in the form of a cross, similar to the cutting portion of fig. 135, fixed in the end of a tube, with streams of water constantly pouring down the tube to wash away and carry up the pulverized stone. Diamond drills were thenceforth used, the first with a crown of eight and a half inches diameter producing a six inch core and subsequently five others gradually smaller by which the hole was carried to a depth of 3,510 ft.; from this point the bore

was deepened to 5,658 ft. with a drill having a crown two inches diameter yielding a core of rather less than one inch. The drilling, mainly in limestone passing through gypsum, anhydrite, copper schist and other intrusive strata, had then reached the Devonian rock, but without traversing coal, after which, for scientific investigation only, it was continued 78 ft. further with a diamond crown one and a quarter inches diameter from which half inch cores were brought to the surface. The boring from first to last was made at the average pace of four and a half feet per working day, it cost about forty shillings the foot and occupied about four years.

The following particulars of the successful use of the gem diamond for boring in search of coal, have been kindly placed at the writer's disposal by Mr. C. B. Elliott, formerly Assistant Commissioner of Crown Lands, Cape Town, who was induced to try native bort, or small complete stones, selected at the Kimberley mines, in place of the Brazilian carbonate in the crowns of drills previously imported from England. The official report made to Sir Charles Mills, K.C.M.G., dated 8th August, 1882, says,—"The experiment has proved a complete success and the Commissioners thinking that the value of bort as a boring agent may, if made generally known, prove advantageous to the Colony, desire me to furnish you with some information on the subject. The last six crowns used of 6 inches diameter were set with bort. It was found that these bored through 1,100 ft. of sandstone and shale, part of which was exceedingly hard from being indurated by contact with intrusive rock. The average boring per crown was therefore 183 ft. and the last crown is nearly as good as new; of the above named six crowns one bored through 322 ft. 7 ins. and was still usable, while another bored through 340 ft." On the question of relative cost between the bort and the carbonate diamonds the report says,—"The boring effected with the latter cost at the rate of twenty-seven shillings and sixpence per foot, while the work done with the bort in the same class of rock cost less than two shillings per foot." The opinion of the Commission was naturally in favour of the bort, but the Report points out that one reason for this great difference in cost was the low price of the previously comparatively valueless stones used, the cost of which, it says, may be

expected to rise so soon as their serviceability for boring purposes is recognized; it also mentions that the stones were carefully selected by the Government Geologist, as a large proportion of the ordinary bort of commerce is quite unsuitable for boring purposes.

Diamonds are also mounted in cylindrical and other plugs for drills and other purposes in a mode patented by M. Gustave Kohler, Paris, 1889. A bar of iron is heated and bent as a hook at one end and the diamond inserted therein, and whilst still at a gentle heat the hook is closed upon it by light blows with a hammer, and so that an angle of the stone may be left projecting or some other indication of its position be apparent. The hook is then reheated, welded solid and cut off; the pieces thus obtained are filed or turned to external shape and dimensions, and so that the diamond may project from the surface or the side of a cylindrical or rectangular piece as required, the portion of the metal in the immediate neighbourhood of the diamond having been first ground away to expose the exact position of the stone.

SECT. II.—CUTTING, WRITING AND SCRIBING DIAMONDS.

The glaziers' diamond in which the gem finds its widest application as a tool, figs. 62, 63, Vol. I. is formed of a minute stone in its natural state embedded centrally in, and so as slightly to project from the flat end of a little oblong block of steel, so that the edge formed by the meeting of two of its planes is parallel with the sides of the block. The opposite end of the latter is pivotted to a socket fixed on a light wooden stem flattened on two sides to be held between the two first fingers, inclined like a pen. This arrangement causes the exposed angular edge of the diamond to at once assume and follow the true line, so long as the side of the steel block runs in contact with the straight edge; and, because this angular edge is slightly curved in the direction of its length, the stem of the instrument is held more or less inclined from the perpendicular, until by trials, the angle is found at which any particular diamond cuts the best, which is that at which the greatest length of its edge rests on the glass.

Mr. E. K. Pitts, a glaziers' diamond manufacturer of grea

experience, has furnished the writer with the following particulars; he says:—Brazilian diamonds being harder and cutting with more certainty are generally preferred, Cape and other diamonds although inferior in these respects are sometimes employed, but are more esteemed on the Continent than in this country. All are set or mounted in their natural condition as found, to preserve their skin or rind intact; although seldom regularly shaped, most approach the typical form of the octahedron, the angles formed by the meetings of their external planes giving three or four, more or less good cutting edges, some few stones have five or six and are proportionately valuable, as all stones may be reset for use so long as one angle remains unworn. The variety of Brazilian diamonds most used is known as Bahia stones, these are generally coloured but include some white and have comparatively flat external planes; the Canavera stones, from another locality, are very hard and white and are more highly esteemed as being rounder stones, that is their planes are more convex which gives the cutting angle more curvature in the direction of its length, hence they cut better and withstand more wear. The skin of the Cape stone is much less hard and, contrary to the Brazilian, until the angle has been a little used is found to scratch more than to cut, therefore, he says, by practised setters these stones after mounting are always prepared for use by rubbing on a piece of glass, after which slight wear they give a fine delicate but not deep cut. Another curious fact, marking moreover the necessity of careful usage as regards the longevity of the implement, is that, glaziers' diamonds used in common by several operators, when sent to be reset, always prove to have the angle worn away to a flat, but that those invariably used by one and the same adept only, are worn equally to either side, so that a ridge or angle still remains although too obtuse to cut.—In making the cut the diamond is drawn once only along the line, with moderate but firm and equal pressure throughout the whole length of the stroke; correctly used, the action is rather that of splitting than cutting and little if any of the material is removed, and the line of division is often not plainly visible throughout its whole length and will yet suffice. Simple as this may be, the glaziers' diamond is easily damaged

in unpractised hands. If used with force when incorrectly inclined, so that an end corner instead of the middle of its edge bears upon the glass, the stone does not run smoothly but jars and scratches instead of making a clean cut, and the corner upon which it rests may then be easily fractured; a few gentle trials, however, soon determine the correct inclination, at which also the stone is felt to bite or hang to the glass, and all danger from this source is avoided. The diamond should never be traversed a second time over the same line, there is no advantage in attempting to deepen the cut and the abrasion left by the first is very destructive to the edge of the stone. When it is felt that some portion of the line has been altogether missed, which may be too long to trust to the subsequent fracture running straight across it, this portion may be retraced, but with care to arrest the traverse just short of the terminations of the line already properly cut to either end of it. The cut being made, the sheet of glass is held by one edge between the thumbs and the bent second joints of the forefingers placed to either side of it, and is steadily bent until the glass breaks clean along the line. Should the cut prove to have been unequal from varying pressure or inclination of the diamond, any small pieces that may in consequence be left upon the fracture are gripped and detached with a pair of flat pliers or they are broken off by tapping them with the closed jaws.

Plate glass diamonds differ from those for crown or sheet glass only in being larger stones used with rather more pressure. To separate plate glass the piece, when large, is held down on a flat table with the line of cut just above its square edge, that the overhanging portion may be steadily bent downwards until it breaks across, the operation usually requiring two or more operators. Smaller pieces are held in the hand and the portion to be broken off is gripped and bent with pliers; others hold such pieces in the one hand and tap with a light round faced hammer on the under side along the cut from the center towards the edge, until the separation occurs.

It is evident that the traverse of the diamond along some form of straight-edge, usually made of hard wood, is essential to an accurate straight line of cut, but, under exceptional

circumstances, such guidance is occasionally dispensed with even with plate glass. As an example, large sheets of the latter are prepared to their dimensions and their edges ground true and smooth at the glass works, but, from some error, it may happen that when it is attempted to place such a piece in position it may prove just too wide to fit within the rebates intended to receive it. Such a case came under the author's observation; when, rather than carry away the glass for alteration, and unprovided with a straight edge, the foreman in charge proceeded to reduce the width by half an inch all along one side of a large piece of plate glass, some 12 feet square, without one. During the process, the glass resting on the ground, was held vertically by two or three assistants; the operator mounted on a tall pair of steps, commenced at the top, and holding the diamond in the unaided hand, cut a straight line downwards for about four feet, parallel with and about half an inch from the side edge. This piece he broke off in small fragments about an inch long by nipping and bending with pliers, then cut and removed a similar length, and so on to the bottom of the sheet. The diamond was held, not as usual by the stem, but by the little steel block in which it is embedded, gripped between the thumb and two first fingers, the first lying on the edge of the block and the points of the thumb and second finger resting on the surface of the glass, with the ends of the third and fourth fingers travelling along the edge of the glass to maintain the diamond at the same distance therefrom throughout. This displayed exceptional dexterity and also perfect acquaintance with the capabilities of the particular diamond employed, as several requisites were uniformly and simultaneously sustained throughout viz.,—the parallelism of the side of the little steel block, not half an inch in width, with the true side edge of the glass, which served as the straight edge, so that the very short line the cutting angle of the diamond, the meeting of two of its planes or facets, should not in the smallest degree wander in its direction from the true line; the uniform inclination of the diamond in the other direction, so as to use the best cutting portion of this minute line; equal and firm pressure; and the constant distance of the diamond from the edge of the glass, in other words, the maintenance of an un-

varying separation between the third and fourth fingers and those grasping the diamond, which also had to be exactly repeated every time the cut was recommenced.

Discs are cut from pieces of sheet glass laid upon circular, baize covered, wood turntables, mounted on central pivots and moved round by hand, the glass held down by flat lead weights. The diamond which has no swivel that its edge may stand as a tangent to the circle, has its stem fixed vertically to a wooden bridge above, so that it can be depressed to the glass and moved and fixed along the bridge for cutting different diameters. Ellipses used in large quantities for picture frames, are cut in a similar machine in which the horizontal turn-table is mounted on an oval movement of similar character to the oval chuck, fig. 424, Vol. V.; or they are cut by hand with the ordinary swivel glazier's diamond traversed around a wood or a zinc template of the required size, the template mounted on a piece of wood about a quarter of an inch thick of the same shape but rather less in dimensions, its under surface covered with baize and the template held down on the glass by weights. The workers in stained glass are very dextrous in traversing the diamond around similar templates cut to the forms of the arbitrary and often abrupt curves at which the different coloured pieces of glass have to be joined.

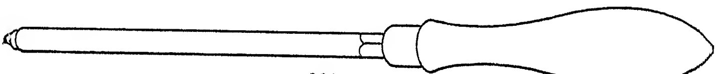
Writing diamonds are fragments of waste or bort, minute pieces split off the gems in their first preparation to shape before they are cut and polished, mounted in the ends of conical brass tubes on penholder handles. They are used to scratch words and marks on glass, steel and other hard materials. Carefully selected fine splinter like pieces left untouched, or sometimes ground to delicate conical points with diamond powder on the lapidary's *mill*, and mounted in holes in the ends of short brass wires, are used in dividing engines for cutting the fine lines of graduations upon the silver circles of theodolites and other high class measuring instruments and upon glass for microscopic purposes, sometimes also for tracing delicate patterns on glass and metal in ornamental turning: all of these delicate scribing points although readily broken by accidents are remarkably permanent in use.

SECT. III.—TURNING TOOLS.

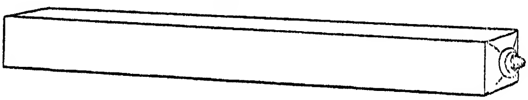
Diamonds used for turning differ in magnitude according to the material and character of the work upon which they are employed, somewhat in their setting and holders, and in being either the gem or carbonate variety; but any given tool will turn any material proper to the action of the diamond to which it can be conveniently applied.

The smallest used for turning hardened steel and watch jewels for horological work, described page 179, Vol. I., are made of minute fragments of the bort of the gem which, preferably, include some portions of the outer skin or rind. These are mounted in the ends of brass or steel wires three or four inches long, in the same manner as the pieces employed for drills; the tool is more usually applied by hand held in

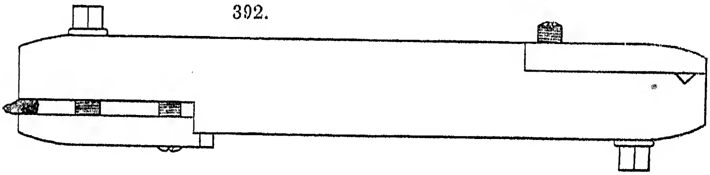
Figs. 390.



391.



392.



the fingers, but the stone in a shorter wire is sometimes brazed or gripped in the ends of holders to be clamped in the sliderest.

Larger pieces or small unbroken stones mounted in nodules of hard brass or silver solder contained in holes made in the ends of round iron or steel rods and in square stems of the forms of figs. 390, 391, are used by hand and in the sliderest for turning steel, emery wheels, granite and other harder stones. Many of the fragments contain no portion of the external skin which is not essential, indeed the diamond when cut and polished into facets as a gem will, under careful

control, turn steel with facility without receiving damage. The experience has been frequently made and of one well known instance "The Engineer," 1867, says:—"Dr. Romney Robinson, Director of the Armagh Observatory, employed a small diamond taken from a ring to turn true the hardened steel axis of a telescope." The work was completed with perfect success and during its progress continuous delicate spiral turnings were obtained, similar to those described in the notice of the manipulation of the carbonate tool in turning hardened steel, page 349, Vol. IV.; at the conclusion, the cut and polished diamond proved to be absolutely uninjured and was reset in the ring.

Turning hardened steel in pieces of any magnitude with the uncut gem by hand or in the sliderest, at best, however, is but a tedious process, to the practice of which as described in the succeeding volume many precautions are essential:—briefly, the work must be more than usually securely chucked and in a lathe with heads and sliderest of ample strength to absorb all vibration; driven at less than half the speed generally employed for turning steel of similar dimensions; the tool constantly well lubricated with water, advanced with care, and the turning carried out by a succession of slow traverses of inconsiderable depth of cut not exceeding the 2000th of an inch in thickness. Under these conditions absolutely hard steel is left true, smooth and highly polished, but failing any and without careful patient manipulation the result is not so satisfactory. The more intensely hard the steel the better it turns, and its equality in hardness is an important factor; if the hardness be at all irregular the turned superficies shows cloudy patches at all its less hard parts, microscopic surface disintegrations, because, taking the other extreme, soft steel will not turn at all the diamond simply dragging and tearing its surface. The gem also after a time rubs *bright*, that is the wear smooths away its cutting angle and it becomes comparatively inoperative; if of sufficient size, it is then a common practice to fracture the exposed part of the stone by a light blow with a hardened steel hammer to give it a fresh cutting angle.

Pieces of carbonate mounted in the rods or stems, figs. 390, 391, now generally replace the gem diamond for all but

horological work, they perform better and remain *grey* or without appreciable wear, and there is practically no risk of their accidental fracture. The stems of the hand tools fig. 390 range from about three eighths to three quarters of an inch in diameter and from six to twelve inches in length, according to the size of the piece of stone and the work upon which it is to be employed; and the stem is cylindrical that the operator may roll it over upon its support, to more easily bring the part of the diamond which cuts or abrades the best into contact with the work. The stem fig. 391 is rectangular for clamping in the sliderest, and the correctness of its setting is then relied upon to give the stone its best cutting position. Fig. 392 shows a sliderest holder to carry a diamond at both ends, the subject of an American patent, in which the carbonate is securely held without any preparation between the roughened side of the stem and a loose jaw, both of soft steel and the latter sometimes notched out. The two faces are brought together on the carbonate by a screw passing through a plain hole in the jaw and, when thus clamped, a set screw in rear of the binding screw is used to force the two sides a little out of parallelism to throw additional pressure on the stone.

Precisely similar hand and sliderest carbonate tools, generally of the larger size, are used for turning emery wheels, marble, granite and porphyry; all peculiarities in their management upon these materials have been already described in preceding pages.

Glass turns, if slowly, yet without the smallest difficulty and equally well with the rough gem or with the carbonate diamond, by hand, but far more conveniently with the tool in the sliderest; the tools require continuous lubrication with paraffine oil and the material is removed in the form of powder. The work revolves at the speed employed for hard wood and ivory, and if cylindrical or a disc is held by its edges in some semi-elastic fixing, as in the rebate of a wood chuck or in a wood spring chuck, fig. 269, Vol. IV.; flat pieces are cemented to wood or metal surface chucks with turner's cement and with that made of beeswax and rosin, used as described pages 239—241, Vol. IV., or with plaster of Paris.

The gem is sometimes used by opticians, but after a time it

rubs *bright* as upon steel and the carbonate is in all respects preferable. Either stone requires a slow and regular traverse and a depth of cut not exceeding the 200th of an inch, with more the glass surface is liable to flake out in numerous tiny shallow pits which have a tendency to perpetuate and are difficult to remove by subsequent finer cuts. In his personal practice the author obtains the best results with a carbonate tool in the sliderest and a succession of cuts less than the above named depth, with the traverse of the tool made in the one direction only, or withdrawn from the glass every time it is returned to its starting point. The perfectly uniform surface thus produced is precisely like that of the finest ground glass, and may then be smoothed and polished with rubbers and the various powders employed for glass polishing, described in previous pages. Except as regards the tedium of the operation there is no difficulty in turning glass to moderate curvatures with the sliderest tool under the control of the curvilinear apparatus, figs. 66—80, Vol. V., by gradually working away the material from the highest to the depressed portions of the curve, and expert operators produce small sharper curvatures and mouldings by patiently excavating little by little with the hand tools; all of which forms are then smoothed and polished with the proper sequence of powders on appropriately shaped rubbers.

SECT. IV.—DIAMOND TOOTHED SAWS.

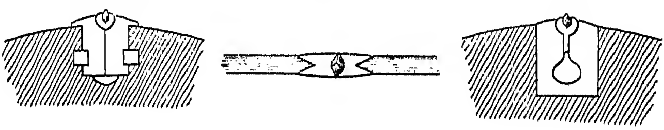
Numerous and many successful methods have been tried to fix the gem and the carbonate diamond in the edges of straight and circular saw blades to replace sand and other abrasives for cutting stone, marble and granite; these may be divided into three groups, viz., those with the diamonds embedded directly in the blade, those in which they are set in plugs or other shaped pieces fixed in apertures in the saw blades and removable or not from it, and those in which the stones are gripped between jaws formed along the edge of the blade.

The first method has to overcome the difficulty of embedding the fragment with sufficient security in metal so thin as even a thick saw blade, so as to prevent its displacement by the constant recurrent shocks it receives during work. Originally

tried with the gem diamond in 1862, the stone was set in a similar manner to that described for the turning tool; a later plan was by filling holes drilled or punched in the edge of the saw blade with a mercury amalgam of silver, tin or bismuth into which the fragment of diamond was forcibly pressed, and when the amalgam had hardened the edges and burr of the hole were punched in around it; and by a third, the stone was first thickly electrotyped with copper, then this surrounded and lengthened into a tail with hard solder and the whole cut into a screw to tightly fit a screwed hole in the saw blade so as to leave but a small portion of the diamond exposed, after which, with all the plugs in place, a portion of the solder and copper was finally ground off from their ends; none of these methods appear to have been successful.

The plugs and jaws have proved practical, but usually so increase the thickness of the saw blade as to make it unsuitable for any but the ordinary sandstones, with which the consequent waste of material is of no great importance; with one exception which will be described, none of them are used upon the rarer varieties of marble which are generally cut into thin slabs and sheets, often less than the thickness of these saws, because they would waste far more than they would produce from the block.

Figs. 393. 394. 395.

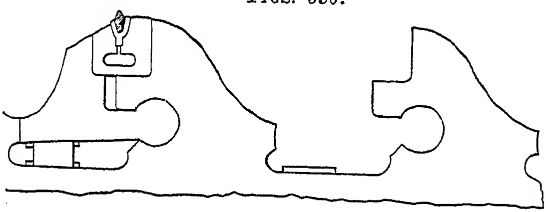


In fixing the carbonates in the thick circular and rectilinear saws, figs. 393—395, patented by Mr. James E. Newton, New Haven, U.S.A., 1869, the lower portion of the stone is enveloped in hard solder and held in cavities between the edges of two flat plates or jaws, fig. 393, which fit in dovetailed notches in the saw blade. The external edges slightly taper that the jaws when driven into the notch may grip the stone, their edge contact is comparatively long but they are further secured by transverse rectangular keys passing through them and the blade; the keys withdrawn a punch is driven into an aperture below the jaws when the latter have to be

displaced. Another form has the jaw made in one piece with a central slot terminating in a large aperture, the external edges tapered and fitting in tapered dovetailed notches as before; the two sides of the jaw when driven in are forced together and grip the stone, which is previously inserted in a forked shaped piece of soft brass hammered into close contact all around its rough sides, and the extremities of the jaws are hollowed out to fit the brass. The jaws are retained only by the dovetailed fitting, like those of the sandstone saws, figs. 160—167, but, unlike those, in which the holders are thicker than the saw blades and the cutters wider than the holders, the jaws in figs. 393—395 do not greatly exceed the thickness of the blades.

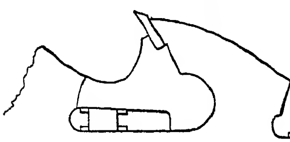
The spring jaw, fig. 395, is itself fixed in a holder in the large carbonate diamond saws, ranging from four to six feet

FIGS. 396.

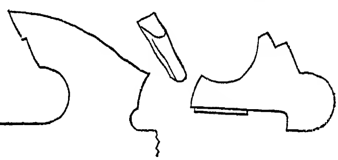


397.

398.



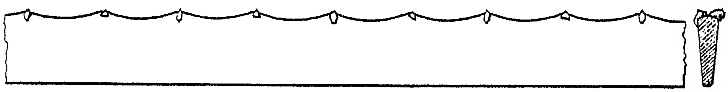
399.



diameter, used at the Emerson Works, Pittsburgh, U.S.A. The saw blade a portion of which is shown in fig. 396, is deeply shaped out around its periphery to receive the dovetailed spring jaws and their locking pieces, one of which is drawn separately, fig. 397, by which the jaws are held in place; and the blade, jaws and locking pieces are all of about the same thickness. Fig. 397 moves as on a joint on the circular portion at the one end of its base within a corresponding aperture pierced through the saw blade, and its opposite end, formed as a short arc struck from the same center, abuts and moves against a counterpart curve in the blade.

The locking pieces are forced outwards from the axis of the saw to secure the jaws and to compress them on the carbonates by steel wedges, driven in between dovetails made in the saw blade and in their bases. The system is a modification of that employed to hold the chisel edged steel cutter blades of another American saw, figs. 398, 399, for some time previously successfully used for sawing wood and sandstone. Every other carbonate or steel cutter in the foregoing is fixed in the plane of the blade of the saw and the remainder to stand a little and equally to right and left beyond its thickness alternately, and thus to copy the set given to the teeth of an ordinary saw; all the diamond saws are driven at a considerable velocity, ranging from 100 to 500 revolutions per minute according to the material upon which they are employed, and are throughout plentifully supplied with streams of water.

Figs. 400.

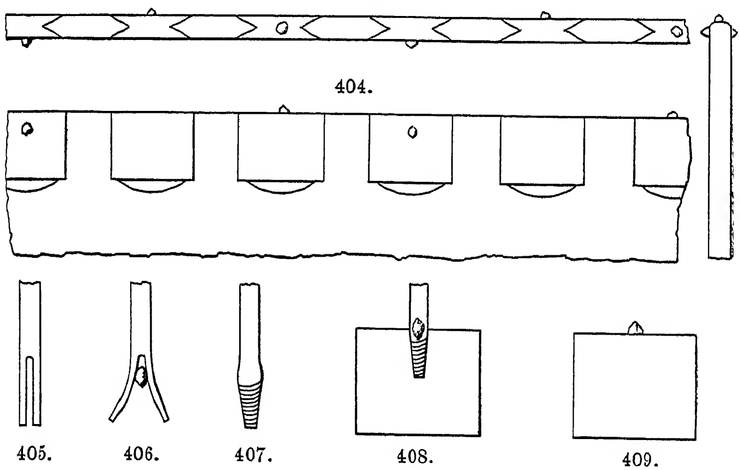


401.

The diamond armed fret saws used for curvilinear stone sawing in fig. 152 are made as slender steel bars from about 24 to 36 inches long by three eighths of an inch deep, and of taper section to assist their traverse around quick curvatures, one eighth of an inch thick on the one and rounded edge in which the diamonds are inserted, and about one thirty second of an inch wide on the other or back edge. A short piece of one of these saws is drawn of its actual size, fig. 400, and again on a smaller scale fig. 401 to show one of the pins at its extremities by which the saw is held and strained in its frame. Small gem diamonds or fragments of their bort are inserted in holes along both arrises, which are first struck for their positions and to raise a burr with a cold chisel, and then deepened by drilling at an angle of 45° into the bar. The holes along one side of the rounded edge are seven eighths of an inch apart, those on the other edge are the same but fall

in the intervals of the first; the diamonds are fixed in the holes with hard solder and then by punching in the burr all around them, every stone projects laterally and equally on its own side of and also partly over the rounded face edge of the blade, which latter is also slightly hollowed away between every two stones to give space for the stone dust and the water. These blades are good examples of dextrous manufacture, but from the small space from one diamond to the next, less than three eighths of an inch, they require very careful management in mounting and straining in the machine, and during use, and to be always flooded with water to avoid their accidental fracture.

FIGS. 402. 403.



The rectilinear diamond saws now extensively used in sawing marble into sheets and slabs, patented by M. Rudolph Arnold of Strasburgh 1885, are made of carefully planished sheet steel and vary from 10 to 14 feet long by 9 to 12 inches wide, by but one eighth of an inch in thickness at their cutting edge, whence they very slightly taper to their back edge. Small pieces of bort of the gem diamond are inserted in removable holders as shown by figs. 402—409, whilst figs. 402—404 represent a portion of the edge of one of these saw blades and its diamonds drawn to their actual dimensions.

The steel blade is cut into a series of rectangular dove-

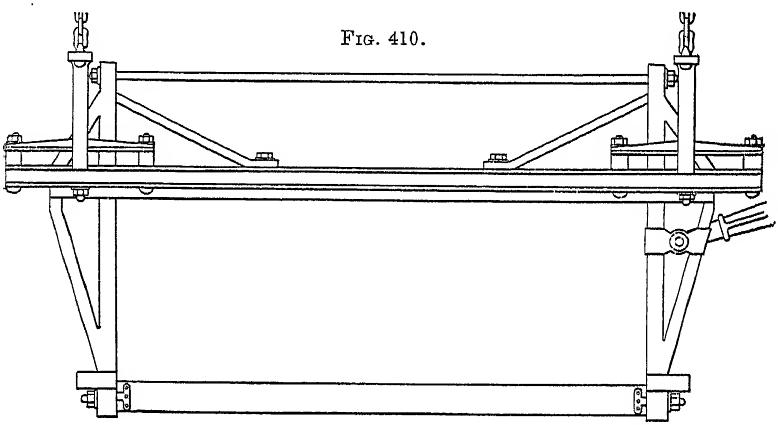
tailed notches, seven sixteenths of an inch long by three eighths of an inch deep, placed one quarter of an inch apart, which are filled by corresponding pieces of steel individually fitted therein, in which the diamond fragments are fixed. The vertical sides of the notches have a trifling taper to secure absolute contact all along between them and these holders when the latter are driven into the blade, and the flat sides of the latter are a little filed away beneath the base of each holder, to the form of the notch for the thumb nail usually made in a sliding box lid, to allow a steel punch to be driven with a hammer to extract any holder when a worn diamond may have to be replaced.

The delicate operation of accurately fixing the diamonds in the holders is effected as follows. The end of a piece of iron wire is drilled with a central hole, just less than the size of the diamond to be inserted, and the wire is sawn diametrically nearly to the depth of the hole fig. 405. The tails thus formed are then opened out, the fragment of bort placed between them with the point or angle to be subsequently exposed in what remains of the original hole fig. 406, and the tails are closed upon the stone. This end of the wire is next heated and welded together into a moderately taper form around and below the stone, and this portion when trimmed to shape with a file is cut into a fine screw thread with a screw plate. The holders figs. 408—9, all prepared nearly to their finished dimensions have corresponding taper screwed holes in their sides or top edges, and each when red hot has a wire with its diamond kernel screwed into it; after which, the long ends of the wires are cut off and the residue filed away to the points of the diamonds. The holders are next fitted and driven into their places in the blade in regular order, the first with a stone projecting from its edge, the second with the projection from its right hand face and the third from the left hand face, and so onwards in repetition for the length of the blade; finally the sides and edges of the holders and the remains of the wires still enclosing the stones are ground away down to the steel blade on a revolving stone, by which process the diamond points are left exposed and untouched. The foregoing method of setting is so perfectly executed that, in the saws that the writer has examined, it is difficult to distinguish the wires

inserted in the holders or the dove tailed joints of the latter in the blades.

For cutting several slabs from the block of marble simultaneously, four or five of these saws, separated by gage blocks to give the thicknesses, are strained in a frame, which, hung by chains from above, working between guides, and partially counterbalanced to regulate the pressure, is reciprocated by a crank and connecting rods after the general manner described in Chapter V.; the motion is rapid, 60 to 90 strokes per minute according to the dimensions of the block being cut, the machine therefore is more than usually massive to absorb

Fig. 410.



vibration and a great quantity of water is constantly and forcibly directed on the saws. The frame for a single saw indicated by fig. 410 is virtually a huge reproduction in iron of the carpenter's wooden bowsaw frames figs. 708—710, Vol. II.; the vertical end uprights are firmly connected to a horizontal iron girder which extends beyond them, and the rectangular form is stiffened and maintained by diagonal braces at either end and above, to withstand the strain of the fourteen foot saw below. Two such frames side by side and as strongly connected by transverse girders and bracings are required when two or more saws are used, and the connecting rod for the crank is then attached to a bracing at the end midway between them. The diamond points of M. Arnold's circular saws used in the ordinary ripping bed fig. 157, are inserted in the edges and sides of holders fixed in notches

around the peripheries in precisely the same manner as for the reciprocating saw blades, and these saws as well as larger made on the same plan are all very successful.

The diamond toothed circular saw has been further developed in the machines lately patented by Mr. James T. Pearson of Burnley. The saws of steel and armed with carbonate points range from 3 to 10 feet in diameter, the largest being one quarter of an inch thick, and are used for all varieties of stone in blocks up to a little over four feet in thickness. The fragments of carbonate of very small size, about three to the carat, are inserted in Bessemer steel after the method contrived by M. Gustave Kohler, already described; the pieces of steel are then shaped into slightly tapering discs or buttons, all alike, three eighths of an inch diameter by three sixteenths thick, with just the point or angle of the carbonate projecting from the arris at their smaller ends. These buttons are placed from either side alternately in corresponding holes pierced in fairly close juxtaposition all around the periphery of the saw blade, within which they are retained by white metal solder applied with an ordinary soldering bit. Beyond its facilities, this system of mounting permits any button the metal of which has worn so as to expose more than about one-third of the piece of carbonate, to be at once driven out with a punch and hammer and replaced by another; this entirely avoids all risk of the loss of a stone and those temporarily withdrawn are remounted in fresh buttons again and again.

The smaller saws run in machines similar to the ripping bed fig. 157; for the larger, the work which may be a single block or two or more piled one on another, is loaded with the proposed line of division parallel with the direction of its traverse upon the table of a truck travelling on wheels along rails between piers of masonry, which latter carry the spindle and frame of the machine as a bridge above. The spindle is cut throughout its length as a square threaded screw and the saw is shifted along it and fixed by nuts on either side, to adjust it to the exact line of cut marked on the stone, and the saw is moved in like manner and refixed from point to point for making parallel cuts; beyond this, the table may be moved round upon a central pivot on the truck for accurately squar-

ing blocks and other angular crosscutting, and the work mounted with its base out of parallelism with the table may then be cut to vertical angles. In some of the machines the saw spindle may be raised or lowered for cutting rebates, and with all the sawn surfaces as left from the saw require little and often no further dressing.

One of Mr. Pearson's saws, 7 feet 3 inches diameter by one quarter of an inch thick, mounted on a screwed spindle five inches diameter in one of the large machines described, has been in continuous use for the past eighteen months during the erection of Heaviley New Church near Stockport, where it has cut all the red Runcorn sandstone blocks used in that edifice. This saw carries 270 carbonate points of a value of about ninety pounds; it is driven at about 400 revolutions per minute, and with a full stream of water constantly playing on the cut to cool the saw blade and wash away the grit, passes through the blocks of stone at the rate of from 6 to 8 inches per minute. Perhaps not the least remarkable feature of all these rectilinear and circular diamond toothed saws is the small, almost minute, size of the stones used in comparison with that of the cutting they perform.

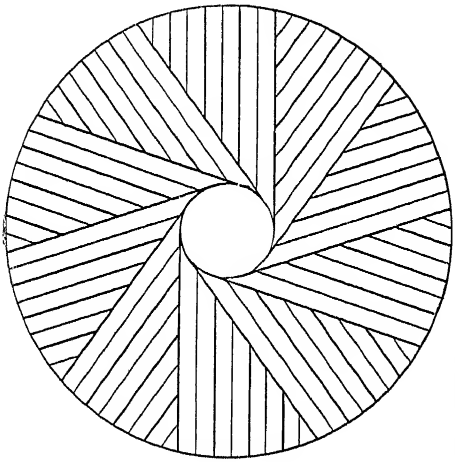
Some attempts have been made to work rectilinear mouldings in stone by employing iron counterparts, similar to those used in the moulding bed figs. 197—199, studded from end to end by spiral lines of diamonds fixed and arranged around the different members so that each diamond just overlaps the work done by its neighbours, or by employing separate plates of appropriate radii armed at their extremities with one or two diamonds, the plates superposed on a spindle after the same manner as the plates shown by fig. 168. Among inherent difficulties, the various members of the counterpart moulding revolve at different surface velocities as they are larger or smaller in diameter, the rate of cutting therefore slightly differs throughout the moulding, and it also is far from easy to obtain sharp internal or external angles; the diamonds upon the larger diameters of the counterpart moreover are the more readily displaced as they have more than their fair share of the work, for they must first cut away the stone to a sufficient depth before those upon the smaller can come into action, unless, indeed, the work be first half done

by preparing the stone somewhat nearly to the profile of the required moulding by other means; and, unlike those in the saws, the stones are few in number in comparison with the work they have to do, hence this particular application of the diamond has not hitherto proved commercially successful.

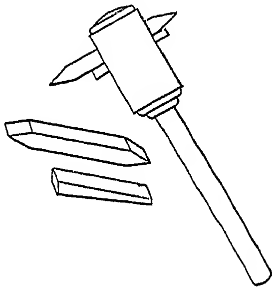
SECT. V.—GROOVING AND SCORING.

Both the gem and the carbonate diamond are employed for dressing millstones, an operation which includes sinking the furrows on the original flat faces of the stones, reinstating these when worn by use, and cracking or scoring the lands

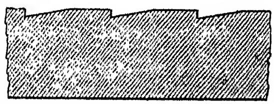
FIGS. 411.



412.



413.



which lie between them. To explain the use of the diamond for these purposes, it should be said that millstones are similar in form to ordinary grindstones and are usually from 4 to 5 feet in diameter; granite is occasionally used, but is not considered so permanent as the Derbyshire Peak gritstone, used for grinding barley and oats, or the French Burr millstone used for wheat. The center of the millstone has a round or square hole called the eye, from which a number of tangential parallel grooves or furrows extend to the circumference fig. 411; and the surface lying between each of these main grooves contains other similar furrows parallel with them, and separated by spaces, called *lands*, portions of the original flat

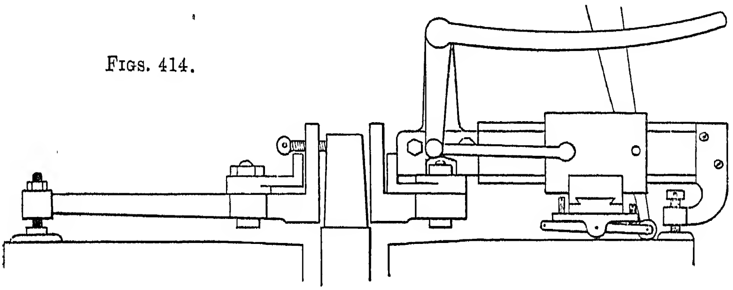
face of the stone; every one of these furrows is about a quarter of an inch deep on the one side, whence it tapers laterally upwards to the space or land lying between it and its neighbour, explained by the section fig. 413; the lands are of the same width as the furrows, and the last process in dressing, called *cracking*, is to fill the surfaces of the lands with minute lines laid in the direction of their length, which shallow lines are also technically known as *stitches*. The surface of the millstone is divided into eight, ten or twelve of such groups, called quarters, these are usually dressed by hand with a mill bill fig. 412, a square bar of steel about seven inches long ground at both ends to chisel edges one and a half inches wide, fixed by a wooden wedge in a diametrical mortise in a turned wood handle eighteen inches long; the tool is held in both hands and worked mainly from the elbows with but little motion of the upper arms, both for sinking the furrows and for cracking.

The gem diamond differently controlled as to its rectilinear traverse and in two distinct modes of scoring or cutting action, has been used during the last thirty years to replace hand dressing, both as a planing and as a revolving cutting tool, the latter revolving either at right angles to a spindle, analogous to a circular cutter, or on the axis of its spindle as a fluting drill. The last named, however, is tedious and unsatisfactory, but two of the other more successful adaptations will be described.

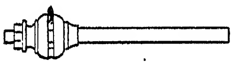
The machine viewed from the side and partly in section and in plan figs. 414, 416, patented by M. Samuel Golay of Paris, 1867, employs a gem or carbonate diamond in revolution. The base consists of a tripod, its horizontal legs in the solid with a central vertical round collar, the latter provided with three binding screws by which the machine is fixed and adjusted centrally on the axis which passes through the under or fixed millstone, or upon a plug temporarily placed in the eye of the running or upper stone after that has been dismounted and reversed; and each leg terminates in a vertical screw and foot, one only shown complete, used to adjust the base of the machine parallel with the surface of the millstone. One leg is provided with a long transverse circular mortise, and in the same plane with this on the opposite side of the

collar there is a flat projecting piece pierced with a vertical hole for a bolt. A horizontal frame with a large curved central aperture, the sides of which are struck from the bolt hole as a center, surrounded by a vertical rim for strength and provided with two opposite tail pieces, rests on the tripod and may be moved partially around its central collar turning

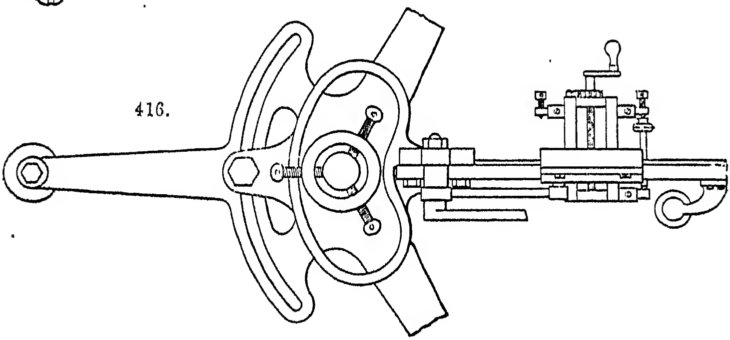
FIGS. 414.



415.



416.



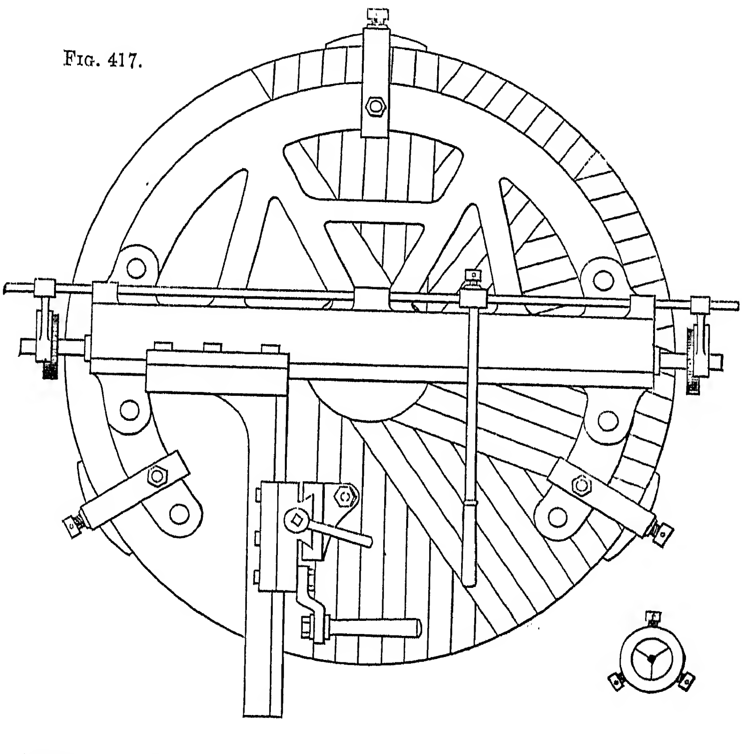
on the bolt as its pivot; and when adjusted to give the mainslide its tangential position, this frame is fixed by the pivot bolt and a second bolt in its circular mortise. The long mainslide for the traverse of the diamond to and fro between the circumference and the center of the millstone, is fixed by two bolts to the lower part of the flat vertical face of a tall upright cast in the solid on the one end of the horizontal frame; its outer end rests on an adjustable foot and the holes for the two bolts are slightly elongated, so that the mainslide may be adjusted to stand parallel or otherwise to the surface of the millstone and then be so fixed.

The spindle shown separately on a larger scale, fig. 415, carries a gem or carbonate diamond gripped between recesses in the inner edges of a flange in the solid with the spindle and a washer brought up by a screw and nuts, and the outer face of this washer is formed as a pulley for the driving band; sometimes two diamonds are used opposite to one another, when one only, a piece of metal, is placed opposite to it to keep the flange and washer fairly parallel. The spindle runs on centers in an adjustable frame pivotted beneath a cross slide, which latter is traversed upon the main slide for the length of the furrows by a link and a hand lever jointed to the top of the upright which carries the mainslide; for the width of the furrows and then over the land to the next the diamond spindle is shifted by the screw of the cross slide, which is provided with a ratchet wheel and detent for its precise movement from point to point, and the spindle is driven by a band, kept taut by a stretching pulley on the end of a weighted lever, from any available power above.

In use, after the stone has been marked out with *black* to show the positions of the deep margins of the main or longest furrow of each quarter, the machine is fixed level with its surface and with its mainslide parallel with one of these marks, the diamond is brought beyond the circumference of the millstone and lowered by the screws bearing on one side of its pivotted frame for the depth of cut. The first groove is then made all along the one edge of the furrow, and followed by a series of others in close juxtaposition all across its width, the cross slide moved every time equally by the ratchet wheel and detent upon its screw. The detent is then reversed and the diamond returned to the penultimate groove, the penetration is increased and all the grooves back to the first are successively deepened to this new level; and this is continued travelling backwards and forwards across the furrow, always stopping one groove short on the one side with every increase of depth to give the furrow the sloping base shown by fig. 413. The diamond is then shifted over the land and the same routine pursued upon this next shorter furrow and so on with the others to the completion of one quarter; after which the machine is shifted round upon the axis of the millstone and refixed by the set screws upon its collar to recommence at the

main furrow of the next quarter. The spindle may be placed to run on a second pair of centers on the inner side of its pivotted frame, when required, to continue the grooves to the center of the stone, and, with the mainslide tilted up at its outer end, to carry on those previously made on the level along a small central width of the surface, which, in some cases, slopes inwards towards the eye of the millstone. The revolving diamond is throughout supplied with a stream of water whilst sinking the furrows and when subsequently cracking the lands.

Fig. 417.



In the machine shown in plan fig. 417, patented by Mr. Robert Young, 1868, the furrows are scored by a fragment of carbonate acting as a planing tool. The details are as follows:—A long horizontal main slide is mounted parallel with and nearly diametrically across the base of the machine, a thick flat ring, from which about a quarter of the circumference on the face side of the main slide is cut away. The main slide stands

about twelve inches above the ring to which it is connected by pedestals at either end and by diagonal bracing behind; a cross slide at right angles, has a long arm at a lower level and carries the diamond carriage, and a vertical projection below this arm rests on the millstone as a support. The ring base stands on the millstone and when adjusted concentrically with it, and so that the arm of the cross slide is parallel with the mark indicating the edge of the main furrow of one of the quarters, the machine is fixed by three screw clamps attached to the ring which abut against the circumference of the stone and, when one quarter is completed, the machine is shifted partly round to its fresh position to plane out the next.

The diamond is fixed in a vertical holder mounted in a slide on the face of the carriage, by which it is adjusted for depth, and it is pulled to and fro along the arm of the cross slide for the length of the furrows by a handle attached to the carriage. The lateral movement from line to line across the width of each furrow, and that over the intervening land from one furrow to the next, is given by a long screw within the main slide, actuated by ratchet wheels and detents at either end fixed to a rod attached parallel with the slide and worked simultaneously by a handle, that can be fixed anywhere along the rod that is most convenient to the operator. The carbonate is held between the edges of three quasi-triangular shaped pieces within a socket, shown separately in plan, forced against it by set screws, and one or two rings of thin sheet india rubber are placed between the upper annular face of the socket and its seat in the holder on the cross slide, to give the diamond a slight elasticity. The stem of the socket is cylindrical that it may be turned round within the holder to place the most serviceable angle of the carbonate across the line of the direction of traverse, after which it is fixed in the holder by a screw and nuts upon the upper end of its stem.

CHAPTER XIII.

VARNISHING, LACKERING, AND BRONZING.

SECT. I.—PREPARATION OF THE VARNISHES AND LACKERS.

Varnishes are solutions of the various resins, which by the varnish makers are commonly called gums, those principally employed are amber, animé, copal, lac, sandarac, mastic, damar, and common resin, dissolved in linseed oil, turpentine, wood naphtha, or spirits of wine. The varnishes are all applied to the surfaces of the woods, metals, or other materials while in the fluid state, like a thin paint, and the solvent is afterwards evaporated, leaving a thin glassy coat of the different resins as a defence from the action of the atmosphere, or from slight friction. Sometimes the resins are used separately, at others two or more are combined in the same varnish; in like manner the solvents are sometimes employed singly, and at other times are combined, according to the qualities required in the varnish.

The durability of the varnishes is mainly dependent upon the comparative insolubility of the resins, their hardness, toughness and permanence of colour. In these respects amber excels all other resins used for varnishes, it resists the action of all ordinary solvents and can only be dissolved for making varnish by fusion at a high temperature, it is hard and moderately tough and its colour is but little influenced by the atmosphere, but unless very carefully selected it is too yellow for delicate works of light colours. Amber is, however, but little used in making varnishes, principally on account of its high price, but partly because the varnish dries slowly and does not attain its full hardness for many weeks.

Animé is nearly as insoluble and hard as amber, the best is of a very pale colour, but it is not nearly so tough as amber. The varnishes made from animé dry quickly, but are very liable to crack and the colour becomes deeper by exposure to light and air. Animé is, nevertheless, extensively used in

making oil varnishes, and most of those called copal varnishes contain a considerable proportion of it, which is substituted principally on account of its quick drying qualities.

Copal is next in durability to amber ; when very carefully selected it is almost colourless and becomes rather lighter by exposure; it is more easily dissolved by heat than either amber or animé, and although softer than these resins it is too hard to be scratched by the nail. Copal is, therefore, a most excellent material for varnish, and numerous attempts have been made to employ it as the basis of a spirit varnish, but hitherto with only partial success. Pure alcohol has little effect on copal; with the addition of a small quantity of camphor, the greater portion of the copal is dissolved, but the camphor impairs the durability of the varnish. Copal may be perfectly dissolved by ether, but this spirit evaporates too rapidly to allow of the varnish being uniformly applied. The essential oils of spruce and lavender have been occasionally employed as solvents of copal, but not with sufficient success to warrant its general adoption in spirit varnishes.

Amber, animé, and copal are usually dissolved for making varnish by fusing the gum and adding linseed oil heated nearly to the boiling point, they are then amalgamated by stirring and boiling, and the varnish is reduced to the required degree of fluidity by the addition of oil of turpentine. They constitute the more important of what are called oil varnishes, are the most durable of all, possess considerable brilliancy, and are sufficiently hard to bear polishing. They are therefore employed for works of the best quality that are exposed to the weather or to much friction, as carriages, house decorations, and japanning.

Lac and sandarac are more soluble than any of the foregoing; they are dissolved in spirits of wine, usually in that known as methylated spirit, spirits of wine rendered nauseous and undrinkable, for excise reasons, by the addition of a small percentage of naphtha or pyroligneous spirit. These resins constitute the basis of what are called spirit varnishes, and are employed principally for delicate objects not exposed to the weather, such as cabinet and painted works.

Lac is much harder and more durable than sandarac, and is the basis of most lackers for hardwood and metal and also of

the so called French polish. Of the three varieties, stick lac, seed lac, and shell-lac, the latter is the most free from colour and the most soluble; it is therefore almost exclusively used in making varnishes and lackers, but the palest shell-lac contains a considerable quantity of colouring matter that renders it inadmissible for varnishing works of a light colour. In addition shell-lac also contains a small quantity of wax and other matters that are only imperfectly soluble in spirits of wine, and therefore give a cloudy appearance to the varnish; but this is of little importance in varnishing dark coloured works, and may be in great measure avoided by making the solution without heat and allowing the more insoluble portions time to precipitate.

Sandarac is softer and less brilliant than shell-lac, and much lighter in colour, it is therefore used for making a pale varnish for light coloured woods and other works for which the dark colour of shell-lac would be unsuited. When hardness is of greater importance than paleness, a proportion of shell-lac is added, but when paleness and brilliancy are required, a small quantity of mastic is added. When the varnish is required to be polished, Venice turpentine is added to give sufficient thickness or body.

Mastic is softer than any of the resins previously mentioned, and is dissolved either in spirits of wine or oil of turpentine, the latter is more generally used on account of its cheapness. With either of these solvents mastic makes a varnish of a very pale colour, that is brilliant, works easily, and flows better on the surface to which it is applied than most other varnishes. It is also tolerably flexible, and may be easily removed by friction with the hand; it is therefore much used for varnishing paintings and other delicate works.

Damar is easily dissolved in oil of turpentine, and when carefully selected is almost colourless; it makes a softer varnish than mastic; the two combined however form an almost colourless varnish, moderately hard and flexible, and well suited for maps and similar purposes.

Common resin is generally dissolved either in turpentine or linseed oil with heat. Varnish made with resin is hard and brilliant, but brittle, and is principally employed to make cheap varnishes for common purposes in house painting, toys

and cabinet work. It is also added to other varnishes in order to improve their brilliancy, but it should be added in small quantities only as a large proportion of resin renders the varnishes brittle.

Linseed oil is extensively employed as a vehicle for the harder resins to which it imparts softness and toughness, and it causes the varnish to dry slowly; but unless the oil is of the purest and palest quality, well clarified, and carefully combined with the resin without excess of heat, it materially darkens the colour of the varnish when first made, which is also liable to become darker by age after it is applied. Linseed oil intended for the best varnishes is clarified by gradually heating it in a copper pot so as to bring it nearly to the boiling point in about two hours; it is then skimmed and simmered for about three hours longer, after which dried magnesia, in the proportion of about one quarter of an ounce to every gallon of oil, is gradually introduced by stirring; the oil is then boiled for about another hour, and afterwards suffered to cool very gradually. It is then removed into leaden or tin cisterns and allowed to stand for at least three months, during which the magnesia combines with the impurities of the oil and carries them to the bottom; the clarified oil is taken from the top of the cistern as it is required without disturbing the lower portion, and the settlings are reserved for black paint. A pale drying oil may also be made as above, by substituting for the magnesia, white copperas and sugar of lead, in the proportions of two ounces of each to every gallon of oil.

Linseed oil when rendered drying by boiling and the addition of litharge and red lead, is sometimes used alone as a cheap extempore varnish. It is heated gradually to bring it to the boiling point in about two hours; then skimmed, and well dried litharge and red lead, in the proportion of about three ounces of each to every gallon of oil, are slowly sprinkled in, and the whole is boiled and gently stirred for about three hours, or until it ceases to throw up any scum or emit much smoke. It is then frequently tested by dipping the end of a feather into it, and when the end of the feather is burnt off, or curls up briskly, the oil is considered to be sufficiently boiled, and is allowed to cool very slowly, during which the principal portion of the driers settle to the bottom. The oil is after-

wards deposited in leaden cisterns screened from the sun and air. When the oil is required to be as pale as possible, dried white lead, sugar of lead, and white copperas are employed instead of the litharge and red lead.

Oil of turpentine is employed as a vehicle for most of the resins, the oil varnishes being generally thinned with it. Mastic, damar, and common resin are generally made into varnishes by dissolving them in oil of turpentine alone, either cold or with very moderate warmth. Varnishes made with turpentine only, dry quicker than those made with oil and are paler coloured, but not so tough and durable. Turpentine varnishes hold an intermediate position between oil and spirit varnishes, and are employed principally on account of their cheapness and flexibility. Turpentine varies considerably in quality and is greatly improved by age; that intended for varnish should be of the best quality, clear and limpid, and be kept for many months or even years, before it is used; when employed alone, as for mastic varnish, care should be taken that it is not passed through an oily measure, as is frequently the case in procuring small quantities.

Alcohol, or methylated spirits, is employed for dissolving sandarac and shell-lac, to make the white and brown hard spirit varnishes and lackers for hardwood or brass, and also for French polish. The varnishes made with alcohol dry much quicker, harder, and more brilliantly than those made with turpentine; but if the spirit contains more than a minute proportion of water it will scarcely dissolve the resins, and when the varnish is applied a very slight degree of moisture in the atmosphere will cause the resins to be precipitated from the solution, giving the varnish a dull, cloudy, or milky appearance. It is therefore of the first importance in making spirit varnishes to procure the alcohol as pure as possible.

Ordinary spirits of wine, however, always contains a considerable proportion of water, and is commonly tested for varnish purposes by saturating a slip of writing paper with the spirit, which is then ignited, and if the flame of the spirit communicates to the paper and the whole is burned, the spirit is considered to be sufficiently good. But if, as frequently happens, the paper should be so far saturated with the water remaining from the evaporation of the spirit as to prevent its

burning, the spirit is rejected as unfit for varnish purposes. Weighing is a far more exact test, the specific gravity of absolutely pure alcohol being nearly ·8, at a temperature of 60°, it may be easily tested by weighing 10 ounces of distilled water in a glass bottle, marking a line on the bottle to show the exact height of the water, and afterwards filling the bottle with spirit to the same height, and weighing it, when the excess over 8 ounces will show the proportion of water with tolerable accuracy; and should it not exceed $8\frac{1}{4}$ ounces, it may be considered to be of very good quality, spirit being frequently used for making varnish when its specific gravity is equal to ·85.

Nearly pure alcohol may be obtained from ordinary spirits of wine, by adding about one-third its weight of well-dried carbonate of potash, agitating the bottle, and then allowing it to stand for ten or twelve hours, during which time the potash will absorb much of the water from the spirit and fall to the bottom; the spirit may then be poured off, and fresh alkali added, and the process repeated until the potash remains quite dry, and the alcohol is then to be freed from the small portion of potash which it holds in solution by distillation in a water bath.

A far more convenient method of concentrating spirit of wine for varnish making, is that discovered by Sœmmering, founded upon the property of ox bladders to allow water to pass through and evaporate out of them, but not to permit alcohol to transpire, or only in a slight degree. According to Sœmmering, as quoted by Ure, "we should take for this purpose the bladder of an ox or calf, soak it for some time in water, then inflate it and free it from the fat and the attached vessels, which is also to be done to the other surface, by turning it inside out. After it is again inflated and dried, we must smear over the outer side twice, and the inner side four times, with a solution of isinglass, by which its texture is made closer, and the concentration of the alcohol goes on better. A bladder so prepared may serve more than a hundred times. It must be charged with the spirits to be concentrated, leaving a small space vacant; it is then to be tightly bound at the mouth, and suspended in a warm situation at a temperature of 122° Fahr., over a sand bath or in the neighbourhood of an oven. Weak

spirit loses its water quicker than strong, but in from six to twelve hours the alcohol may be concentrated when a suitable heat is employed. Alcohol may also be strengthened, as Sœmmering has ascertained, when the vessel that contains the spirit is bound over with a bladder which does not come into contact with the liquor." The coating of the bladder with the solution of isinglass appears, however, not to be essential to the success of the method for varnish purposes, as, upon experiment with an unprepared bladder, spirits of wine of s. p. 8·54 was brought in a few hours to s. p. 8·11, showing it to contain about 95 per cent. of pure alcohol.

Naphtha, or the spirit procured by distillation from pyroligneous acid, and commonly known as vegetable or wood naphtha, is frequently employed instead of spirits of wine for making cheap varnishes. It dissolves the resins more readily, but the varnish is less brilliant and the smell of the naphtha is objectionable. It is therefore never employed for the best works.

The preparation of oil varnishes requires the application of considerable heat, and owing to this and the highly inflammable nature of the materials, the process is attended with considerable risk of fire, it should therefore always be conducted in detached buildings constructed expressly for the purpose. Owing partly to the necessity for this precaution, and the circumstance that oil varnishes are greatly improved by being kept in leaden cisterns for some months before they are used, the preparation of oil varnish is carried on almost exclusively as a separate manufacture, the details of which are greatly varied and are mostly kept secret.

The following particulars of the methods followed in making oil and other varnishes, to which but little could be added, are extracted from a paper written in 1833 by Mr. Neale, for which he was awarded a gold medal by the Society of Arts.

" The copper pot employed to make the varnish, is called a *gum-pot*, and measures about 2 feet 9 inches in height, and 9½ inches diameter externally. The bottom is hammered out of a single piece of copper, and fashioned like a hat without a brim; it is about 9 inches deep, and three-eighths of an inch in thickness. The upper part of the pot is formed as a cylinder, of sheet copper, about 2 feet 2 inches in height, and

of sufficient diameter to slip about 2 inches over the upper edge of the bottom piece, to which it is firmly rivetted. A wide flange of copper, to support the pot, is also fixed just beneath the lower edge of the cylinder, and a strong iron hoop is fixed a little above the line of the rivets, to serve for the attachment of the horizontal handle, which is made as a nearly straight rod, one inch square, flattened at the end, and 2 feet 8 inches long.

"The *stirrer* is a copper rod about three-quarters of an inch diameter, and 3 feet 6 inches long, flattened at the one end to $1\frac{1}{2}$ inch in breadth for about 8 inches in length, and fitted at the opposite end with a short wooden handle.

"The ladle, which should contain about two quarts, is also of copper beaten out of the solid, and rivetted to a handle of the same metal, 3 feet 6 inches long, and fitted with a wooden handle like the stirrer.

"The copper *jack*, for pouring hot oil into the gum-pot, is made in the form of a pitcher, with a large handle and a wide spout; it contains two gallons. The brass or copper sieve, for straining the varnish, is about 9 inches diameter, and contains sixty meshes to the inch. The copper funnel, for straining the boiling varnish, is large enough to receive the sieve, and should be well made with lapped seams, as solder would be melted with the heat.

"The tin pouring pot, to hold three gallons, is formed exactly like a garden watering-pot, only smaller at the spout, and without any rose. This is never to be used for any purpose except pouring oil of turpentine into the varnish.

"A small broom, termed 'a swish,' used for washing out the gum-pot every time after use, is made from cuttings of cane tied to a small handle like a hearth-broom; the head is 5 inches long, and 5 inches round. This should be washed in turpentine, and kept very clean.

"A three-footed iron trevet, with a circular top, is employed to support the gum-pot. The feet of the trevet are about 16 inches in height, and spread wider at the bottom than the top, which is made of such a size that the pot will fit easily into it, the flange resting on the top.

"An ash-bed should be prepared near the fire, upon which to place the gum-pot when the varnish is ready for mixing, or

when the heat is becoming too great. This is prepared by sifting some dry ashes through a fine sieve, to make a smooth layer about $1\frac{1}{2}$ inch thick, and a little larger than the bottom of the gum-pot.

"Place the trevet in a hollow in a field, yard, garden, or outhouse, where there can be no danger from fire; raise a temporary fire-place round the trevet with loose bricks after the same manner that plumbers make their furnaces; then make up a good fire with either coke, coal, or wood charcoal which is far preferable; let the fire burn to a good strong heat, set on the gum-pot with 3lb. of gum copal; observe that if the fire surround the gum-pot any higher than the gum inside, it is in great danger of taking fire. As soon as the gum begins to fuse and steam, put in the copper stirrer and keep cutting, dividing, and stirring the gum to assist its fusion; and if it feels lumpy and not fluid, and rises to the middle of the pot, lift it from the fire and set it on the ash-bed, and keep stirring until it goes down (meantime let the fire be kept briskly up); then set on the gum-pot again, and keep stirring until the gum appears fluid like oil, which is to be known by lifting up the stirrer, so far as to see the blade. Observe, that if the gum does not appear quite fluid as oil, carry it to the ash-bed whenever it rises to the middle of the pot, and stir it down again (keep up a brisk fire), put on the pot and keep stirring until the gum rises above the blade of the stirrer; call out to the assistant, 'Be ready!' He is then, with both hands, to lay hold of the copper pouring-jack, charged with (one gallon) clarified oil, and lean the spout about one inch and a half over the edge of the gum-pot. Let him keep himself firm, steady, and collected, and not flinch, spill, or pour the oil, which would perhaps set all on fire. Observe, when the gum rises within five inches of the pot-mouth, call out, 'Pour!' The assistant is then to pour in the oil very slowly until towards the last, the maker stirring during the pouring.

"If the fire at this time is strong and regular, in about eight or ten minutes the gum and oil will concentrate and become quite clear: this is to be tested by taking a piece of broken window glass in the left hand, and with the right lifting up the stirrer and dropping a portion of the varnish on it; if it appears clear

and transparent, the oil and gum are become concentrated or joined together. It is now to be further boiled until it will string between the finger and thumb: this is known by once every minute dropping a portion on the glass and taking a little between the forefinger and thumb: if it is boiled enough it will stick strong, and string out into fine filaments, like bird-lime; but when not boiled enough, it is soft, thick, and greasy without being stringy. The moment it is boiled enough, carry it from the fire to the ash-bed where let it remain from fifteen to twenty minutes, or until it is cold enough to be mixed; have at hand a sufficient quantity of oil of turpentine to fill the pouring pot, (2 gallons) begin and pour out with a small stream, gradually increasing it, and if the varnish rises rapidly in the pot, keep stirring it constantly at the surface with the stirrer to break the bubbles, taking care not to let the stirrer touch the bottom of the pot, for if it should, the oil of turpentine would be in part converted into vapour, and the varnish would run over the pot in a moment: therefore during the mixing, keep constantly stirring as well as pouring in at the same time. Have also a copper ladle at hand, and if it should so far rise as to be unmanageable, let the assistant take the ladle and cool it down with it lifting up one ladleful after another and letting it fall into the pot. As soon as the varnish is mixed, put the varnish sieve in the copper funnel placed in the carrying tin, and strain the varnish immediately; empty it into open mouthed jars, tins, or cisterns, there let it remain to settle, and the longer it remains the better it will become. Recollect when it is taken out, not to disturb or raise up the bottoms.

"Instead of the ash-bed a circle of loose bricks four courses high may be erected to support the gum-pot. The bricks are to be laid so that when the gum-pot is set within, it will rest securely by its flange with the bottom about six inches from the ground. Upon this brick-stand set the pot every time there is occasion to carry it from the fire. Near the stand an iron trevet may be placed, upon which to turn the gum-pot every time after it is washed out, as, by so doing, it will always be kept clean and cool gradually, for by cooling rapidly copper oxidises very quickly. Near the trevet have the swish broom and also a large wide tin jack or other vessel to receive

the washings. Have also at hand a copper ladle, and a tin bottle with turpentine, for washing with when wanted.

"The moment the maker has emptied the gum-pot, throw into it half a gallon of turpentine, and with the swish immediately wash it from top to bottom, and instantly empty it into the tin jack. Afterwards with a large piece of woollen rag dipped in pumice powder, wash and polish every part of the inside of the pot, performing the same operation on the ladle and stirrer; rinse them with the turpentine washings, and at last rinse them altogether with clean turpentine, which also put to the washings; wipe dry with a clean soft rag, the pot, ladle, stirrer and funnel, and lay the sieve so as to be completely covered with turpentine which will always keep it from gumming up.

"Eight pounds of Copal takes in general from sixteen to twenty minutes in fusing, from the beginning till it gets clear like oil; but the time depends very much on the heat of the fire and the attention of the operator. During the first twelve minutes while the gum is fusing the assistant must look to the oil, which is to be heated at a separate fire in a copper pot, large enough to contain double the quantity required. The oil should be brought to a smart simmer, for it ought neither to be too hot nor too cold, but in appearance beginning to boil, which the assistant is strictly to observe, and when ready, call to the maker, then immediately each take hold of one handle of the boiling pot and carry it to the ash-bed, the maker instantly returning to the gum-pot, while the assistant ladles the hot oil into the copper pouring jack, bringing it and placing it at the back of the gum-pot until wanted.

"A thick piece of old carpet, free from holes, should be kept at hand in case the gum-pot should take fire; should this happen, let the assistant throw the piece of carpet quickly over the blazing pot, holding it down all round the edges; and in a few minutes the fire will be smothered.

"After the oil has been mixed with the gum, a brisk, strong fire should be kept up, until a scum or froth rises and covers all the surface of the contents, when it will begin to rise rapidly. Observe when it rises about two-thirds the height of the pot, carry it from the fire, and set it on the ash-bed, or brick-stand, stir it down again; and if driers are to be added, scatter in a

few by a little at a time; keep stirring, and if the frothy head goes down, put the pot on the fire, and introduce *gradually* the remainder of the driers, always carrying the pot to the ash-bed when the froth rises about two-thirds the height of the pot. In general, if the fire be good, all the time a pot requires to boil from the time of the oil being poured in, is about three-and-a-half or four hours; but *time* is no criterion for a beginner to judge by, as it may vary according to the weather, the quality of the ingredients, or the heat of the fire; therefore, about the third hour of boiling, try it on a bit of glass, and keep boiling it until it feels strong and stringy between the fingers, as before mentioned." The foregoing directions are, with very little differences, to be observed in making all sorts of copal varnishes, excepting the quantities of oil, gum, &c., a few of which will be now added.

Copal varnish for fine painting, &c. Fuse 8 lbs. of the very cleanest pale African gum copal, and, when completely fluid, pour in two gallons of hot oil; let it boil until it will string very strongly; and in about fifteen minutes or while it is yet very hot, pour in three gallons of turpentine, taken from the top of a cistern. Perhaps during the mixing a considerable quantity of the turpentine will escape from heat and evaporation, but the varnish will be so much the brighter, transparent, and fluid, and will work freer, dry quickly, and be very solid and durable when dry. After the varnish has been strained, if it be found too thick, before it is quite cold, heat as much turpentine and mix with it as will bring it to a proper consistence.

Artist's virgin copal. From a select parcel of scraped African gum copal pick out the very fine transparent unbroken pieces, which are pale and round like drops of crystal, break these small and dry in the sun or before a fire and when cool bruise them into coarse powder. Then take some pieces of broken bottles or other flint glass, boil in soft water and soda and pound into powder like the gum, boil this a second time, strain off and wash in three or four waters that the powder may be perfectly clean from grease or other impurities, and dry in an oven or before a fire. When perfectly dry thoroughly mix 2 lbs. of the powdered glass with 3 lbs. of the powdered copal, fuse in the gum pot constantly stirring until melted;

the glass prevents the gum from adhering together so that a very moderate fire will serve. When sufficiently run, pour in three quarts of very hot clarified oil and let boil until the mixture strings freely between the fingers; the mixing should be conducted at a rather greater heat than if for body varnish, besides which, being but a small quantity it sooner cools. Finally pour in five quarts of old turpentine, strain immediately and pour into an open jar or large glass bottles, expose to air and light but not to sun or moisture until of sufficient age for use; this produces the finest copal varnish for oil paintings.

Cabinet varnish. Fuse 7 lbs. of very fine African gum copal, when well dissolved pour in half a gallon of pale clarified oil; and when clear mix with it three gallons of turpentine; afterwards strain, and put aside for use. This, if properly boiled, will dry in ten minutes; but if too strongly boiled will not mix at all with the turpentine; and *sometimes*, when boiled with the turpentine it will mix and yet refuse to amalgamate with any other varnish less boiled than itself; hence its successful manufacture requires considerable practical experience. This varnish is very apt to chill all other oil varnishes to which it may be added, and it is principally employed as a quick drying varnish for the occasional use of japanners, cabinet and coach painters. Cabinet varnish is, however, more generally made with animé than copal.

Best body copal varnish, used for the body parts of carriages and other objects intended for polishing. Fuse 8 lbs. of fine African gum copal, add 2 gallons of clarified oil; boil it very slowly for four or five hours, until quite stringy, and mix it off with 3½ gallons of turpentine.

The foregoing being made of the finest copal without driers are the palest and best of the copal varnishes, possessing great fluidity and pliability, but they are rather slow in drying and retain for months so much softness that they will not polish well until they give out a moisture and become hard, after which they are very durable. When paleness is not of primary importance a second quality of gum is used, and when the varnish is required to dry quickly sugar of lead or white copperas are introduced as driers, either singly or combined, in the proportion of from half a pound to one pound to each of the quantities above quoted, but driers are

always injurious to the colour, brilliancy and durability of varnishes. When a varnish is required that will dry quickly and hard without driers, gum animé is substituted for the copal, but it is less durable and becomes darker by age. Frequently animé varnish is mixed with copal varnish by the maker while both are hot, in different proportions according to the quality required; one pot of animé to two of copal being used for a moderately quick drying body varnish of good quality, and two pots of animé to one of copal for a quicker drying body varnish of common quality.

Carriage varnish is made much the same as common body varnish, except that to 8 lbs. of gum of second quality about 2½ gallons of oil, and 5½ gallons of turpentine are used with driers. This varnish is boiled until very stringy, and is used for the wheels and under framework of coaches and other objects not requiring to be polished; it is intermediate in quality between body varnish and the following.

Wainscot varnish consists of 8 lbs. of second quality of gum animé, 3 gallons of clarified oil, ¼ lb. of litharge, ¼ lb. of dried sugar of lead, ¼ lb. of copperas, well boiled until it strings very strongly and mixed with 5½ gallons of turpentine. This varnish dries quickly and is principally used for house painting and japanning. When a darker varnish is required as for mahogany a small portion of gold size may be mixed with it.

Pale Amber Varnish. Fuse 6 lbs. of fine, picked, very pale amber in a clean gumpot, and pour in 2 gallons of hot clarified oil; boil until it strings well and strongly and then mix with 4 gallons of turpentine. This will be as fine and work as freely as body copal and will flow well upon any surface to which it may be applied, it dries slowly but becomes very hard and is the most durable of all varnishes; it is sometimes added to copal varnishes to improve their hardness and durability. Another method is to melt 1 part, by weight, of amber in a covered iron pot, which is then taken from the fire and 2 parts of the best white, painters' varnish are thoroughly stirred in with a glass or wood rod, the mixture is then returned to the fire and still continuously stirred is allowed to boil; when cool 1 part of turpentine is added and stirred in in the same manner; a further quantity of turpen-

tine is added for a thinner varnish. Amber varnish is most celebrated in the lustrous backs of the violins made by the Old Masters, from its cost it is not now much used.

In making any oil varnish, it should be said, that, the more carefully and thoroughly the gum is fused, the greater is the quantity and the stronger the quality of the result. The more regular the heat and the more protracted the boiling, the more fluid the varnish and the more freely it will flow or extend over the work to which it is applied. If from undue heat the mixture of oil and gum is too rapidly brought to the stringy condition, the varnish will then require more than its correct proportion of turpentine to thin it, with the effect that its oily gummy character is reduced, it flows less well in laying on and is less durable. The greater the proportion of oil used, the tougher and softer the varnish and the less its liability to crack; and lastly, with increase in the proportion of gum, the thicker the coats that may be laid, the firmer the varnish will set and the quicker it will dry.

All body varnishes, and those intended to be polished should have 1½ lbs. of gum to each gallon of varnish when it is strained off and cold. All carriage or wainscot varnishes, or those not intended to be polished should have full 1 lb. of gum to each gallon. But the quantity of gum required to bring varnish to its proper consistence, depends very much upon the degree of boiling it has undergone; therefore when the gum and oil have not been strongly boiled the varnish requires less turpentine to thin it, but when boiled stronger than usual a larger proportion of turpentine is requisite; if the mixing of the varnish with the turpentine be commenced too soon, and the pot is not sufficiently cool, there may be considerable loss by evaporation.

Copal varnishes should be made at least three months before they are required for use, the longer they are kept the better they become, but when it is necessary to use the varnishes before they are of sufficient age, they should be left thicker than usual.

In the preparation of spirit and turpentine varnishes scarcely any apparatus is required, generally speaking, the

process is almost limited to mixing the resins and solvent together and agitating the whole until the resin is thoroughly dissolved. Heat is not usually necessary, and although frequently resorted to in order to facilitate the dissolution of the resins, in most instances only a moderate degree of warmth is required, consequently the preparation is far more manageable than that of oil varnishes and entails much less risk of accident. The resins should be thoroughly free from moisture, and broken into small pieces, that they may dissolve more quickly, and all impurities carefully picked out; the finest and clearest pieces are generally selected and set aside for making small quantities of varnish of a superior quality. Sometimes, with the view of expediting the dissolution of the resins, they are finely powdered before they are added to the solvent; but in this case it is necessary that the agitation should be maintained from the time the resin is added until it is thoroughly dissolved, otherwise it is liable to agglutinate into one mass that is afterwards very difficult of solution.

In making turpentine varnishes without heat, in quantities of ten or twelve gallons, the resin and turpentine are generally introduced into a large can with a wide mouth, and agitated by stirring with a stout stick; a number of wooden pegs or nails being usually driven into the stick near the lower end to increase its effect.

Spirit varnishes are generally made in smaller quantities, and to prevent evaporation, the mouth of the vessel is mostly closed and the vessel itself is agitated. In making quantities of four to eight gallons, the resin and solvent are sometimes introduced into a small cask capable of containing about double the quantity, mounted to revolve on central bearings at the ends. The cask is made to rotate either with continuous motion by a winch-handle, or with an alternating motion, by means of a cord passed around the barrel and terminating in a cross handle which the operator pulls to give motion to the barrel in the one direction, and the momentum suffices to coil up the cord ready for the following pull which causes the barrel to revolve in the opposite direction, and so on continually. Quantities of varnish not exceeding two or three gallons, are generally agitated in a tin can rolled backwards and forwards upon a bench covered with an old carpet,

or a sack; but whatever method be adopted, the agitation should be continued without intermission until the resin is sufficiently dissolved to prevent the risk of its becoming agglutinated, the time required depends upon the solubility of the resin and the strength of the spirit, but is commonly from three to four hours. The further agitation for the thorough solution of the resin may be either continuous or intermittent, according to convenience, but is not abandoned until the solution is perfect; when that is judged to be complete, the varnish is poured into another vessel for examination, and if any of the resin be not perfectly dissolved the whole is returned to the vessel for further agitation. When all is dissolved, the varnish is allowed to stand for a few hours that any impurities may settle to the bottom, and the clear liquid is lastly strained through muslin or lawn into bottles and allowed to stand for a few days before use.

Very small quantities of varnish are generally made in glass bottles, large enough to contain about one-third more than the quantity introduced, and they are shaken up at frequent intervals; but although from the small bulk of the resin it cannot agglutinate into so insoluble a mass as when larger quantities are made, still when the agitation is intermitted, several days are frequently required before the resins are entirely dissolved, as the solution depends more upon the amount of agitation than the length of time the resins are submitted to the action of the solvent. With the view of preventing the agglutination and facilitating the dissolution of the resins, coarsely pounded glass is sometimes introduced with the resin in the solvent; in this case the glass is thoroughly washed and dried, as already mentioned, and afterwards sifted to exclude all the smaller particles, which have little effect in preventing the aggregation of the resin, and are more difficult to separate from the varnish.

When heat is employed in making spirit varnishes the lowest temperature should be used that will suffice to dissolve the resins, otherwise there is risk of losing a considerable portion of the alcohol by evaporation and thereby reducing the strength of the spirit, the varnish is also liable to be made of a darker colour by excess of heat; those containing shell-lac are less clear and hard prepared with heat than when made cold,

as the heated spirit dissolves the greater portion of the wax contained in the shell-lac, which then becomes disseminated throughout the mass; when the solution is made without heat the principal portion of the wax and other impurities remain undissolved at the bottom.

In making large quantities of spirit varnish with heat, a still and worm are sometimes employed in order to prevent loss by evaporation; the still is heated by a steam or water-bath, and the resins and solvent are agitated by a stirring-rod passing through a stuffing-box in the head of the still. Quantities of two or three gallons are generally made in a tin can, which is dipped at frequent intervals into hot water and agitated between every dip by rolling; but in this case it is necessary to loosen the cork every time the can is immersed in the hot water to allow the vapour of the spirit to escape, otherwise the cork would be driven out with great force and some of the spirit thrown on the fire with risk of serious accident. Glass bottles, although convenient from their transparency, should not be employed for making varnish with heat as they are liable to break from the alternations of temperature. They are nevertheless convenient for making small quantities; in this case the safer practice is to heat the water only to a moderate degree, and to allow of the continuous escape of the vapour through a small notch cut lengthways in the cork, which may be closed by the thumb when the bottle is shaken. There is, however, always some risk of accident in making spirit varnishes near an open fire; a water or sand-bath, placed on the top of a stove so as to be heated only in a moderate degree, will generally be found to afford sufficient warmth and is, perhaps, the most safe and convenient arrangement for occasional purposes. Shell-lac never requires more than a very moderate warmth to dissolve it, and the solution is frequently made in stone bottles placed near a fire and shaken occasionally. When it is required to be very clear as for metal lacker, it should be passed through filtering paper before it is bottled. It need scarcely be observed, that all the utensils employed in making spirit varnishes should be perfectly clean and dry, as the least moisture or even a damp atmosphere is liable to deteriorate the quality of the varnish.

Best white hard spirit varnish to bear polishing is made by

adding 2 lbs. of the best picked gum sandarac to 1 gallon of spirits of wine, they are then shaken up without intermission for about four hours, or until the gum is quite dissolved, 18 ounces of Venice turpentine are then moderately warmed in a water bath, to make it fluid, and poured into the varnish to give it a body. The whole is then well agitated for about one hour, and afterwards strained and put into bottles, which should be kept well corked to prevent the evaporation of the spirit; after standing about a week the varnish is fit for use. This varnish may be made sufficiently pale to be used on white work when the clearest and palest pieces of the gum are carefully selected. When the work does not require to be polished the proportion of Venice turpentine may be reduced one half.

White hard varnish is also made with $3\frac{1}{2}$ lbs. of gum sandarac to 1 gallon of spirits of wine, and when this is dissolved one pint of pale turpentine varnish is added and the whole is well shaken until thoroughly mixed. Another white hard varnish is made with 2 lbs. of gum sandarac, 1 lb. of gum mastic, and 1 gallon of spirits of wine.

White spirit varnish for violins is made with 2 lbs. of mastic to 1 gallon of spirits of wine, and 1 pint of turpentine varnish. This may be made either in the same manner as the white hard varnish, or the ingredients may all be mixed together in a tin can placed in a warm situation near a fire and shaken occasionally until dissolved.

Brown hard spirit varnish is made in the same manner as the white, but shell-lac is generally used instead of sandarac. Thus a very excellent brown hard spirit varnish that will bear polishing is made with 2 lbs. of shell-lac to 1 gallon of spirits of wine, and after they are amalgamated, 18 ounces of Venice turpentine are warmed and added exactly as described for the best white hard varnish. Another very good brown hard spirit varnish consists of 2 lbs. shell-lac, 1 lb. of sandarac, and 2 ounces of mastic, dissolved in 1 gallon of spirits of wine. A lighter coloured varnish is made with 2 lbs. of sandarac, 1 lb. of shell-lac, and 1 gallon of spirit. After the resins are dissolved 1 pint of turpentine varnish is added and the whole is well mixed by agitation.

Hardwood lacker is made like the brown hard varnish with

2 lbs. of shell-lac to 1 gallon of spirits of wine, but without turpentine. Another hardwood lacker is made with 1 lb. of seed lac and 1 lb. of white resin dissolved in 1 gallon of spirits of wine.

French polish is made in a great variety of ways, but the simplest and probably the best, consists of 1½ lbs. of shell-lac dissolved in 1 gallon of spirits of wine without heat. Copal, sandarac, mastic and gum arabic are frequently used, partly with the view of making the polish of a lighter colour and partly to please the fancy of the polisher, the proportions of the different gums are varied almost infinitely, but with little advantage. Another variety is made with 12 ounces of shell-lac, 6 ounces of gum arabic, and 3 ounces of copal to 1 gallon of spirits of wine. When a dark coloured polish is required, ½ lb. of Benzoin is added to 1 lb. of shell-lac dissolved in 1 gallon of spirits, or 4 ounces of guaiacum are added to 1½ lbs. of shell-lac; at other times the polish is coloured to the required tint with dragon's blood.

The shell-lac alone makes the hardest and most durable polish, and it is a frequent practice to make the latter rather thicker than required for use, as it may be readily thinned by the addition of spirit, and to avoid any risk of its being too thin in the first instance, the proportion of shell-lac is frequently made 2 lbs. to the gallon of spirit. Other resins are sometimes added with the view of making the polish tougher. Hence sometimes the ingredients are 1½ lbs. of shell-lac, 4 ounces of seed lac, 4 ounces of sandarac, and 2 ounces of mastic to the gallon of spirit; at other times the proportions are 2 lbs. of shell-lac and 4 ounces of Thus, the resin of the spruce fir, to the gallon of spirit.

When a lighter coloured lac varnish, or polish is required than can be made with the palest ordinary shell-lac, the bleached lac, sold under the name of white lac, may be employed with advantage. The varnish made with the white lac is at first almost colourless, but becomes darker by exposure to the light.

Various modes have been adopted for bleaching lac varnish. Mr. Field's process for which he received an award from the Society of Arts, 1827, is as follows: "Six ounces of shell-lac, coarsely pounded, are to be dissolved by gentle heat in a pint

of spirits of wine; to this is to be added a bleaching liquor, made by dissolving purified carbonate of potash in water, and then impregnating it with chlorine gas till the silica precipitates, and the solution becomes slightly coloured. Of the above bleaching liquor add one or two ounces to the spirituous solution of lac, and stir the whole well together; effervescence takes place, and when this ceases, add more of the bleaching liquor, and thus proceed till the colour of the mixture has become pale. A second bleaching liquid is now to be added, made by diluting muriatic acid with thrice its weight of water, and dropping into it pulverized red lead, till the last added portions do not become white. Of this acid bleaching liquor, small quantities at a time are to be added to the half-bleached lac solution, allowing the effervescence, which takes place on each addition, to cease before a fresh portion is poured in. This is to be continued till the lac, now white, separates from the liquor. The supernatant fluid is now to be poured away, and the lac is to be well washed in repeated waters, and finally wrung as dry as possible in a cloth." Mr. Luning recommends another process, viz., "Dissolve 5 ounces of shell-lac n a quart of rectified spirits of wine; boil for a few minutes with 10 ounces of well-burnt and recently-heated animal charcoal, when a small quantity of the solution should be drawn off and filtered; if not colourless, a little more charcoal must be added. When all colour is removed press the liquor through silk, as linen absorbs more varnish, and afterwards filter it through fine blotting paper." Dr. Hare adopts a different procedure, he says, "Dissolve in an iron kettle one part of pearlash in about eight parts of water, add one part of shell or seed lac, and heat the whole to ebullition. When the lac is dissolved cool the solution and impregnate it with chlorine gas till the lac is all precipitated. The precipitate is white, but the colour deepens by washing and consolidation; dissolved in alcohol, lac bleached by the process above mentioned yields a varnish which is as free from colour as any copal varnish." A nearly colourless varnish may also be made by dissolving the lac as in Dr. Hare's process; bleaching it with a filtered solution of chloride of lime, and afterwards dissolving the lime from the precipitate by the addition of muriatic acid. The precipitate is then to be well washed in several

waters, dried, and dissolved in alcohol, which takes up the more soluble portion forming a very pale but rather thin varnish, to which a small quantity of mastic may be added.

Attempts are frequently made to combine copal with all the spirit varnishes, to give them greater toughness and durability, and although copal cannot be entirely dissolved even in pure alcohol, still a moderate portion will be taken up by strong spirits of wine when a temperature of about 120° is employed with frequent agitation of the varnish. In this manner a light coloured varnish may be made with ¾ lb. of shell-lac, ¾ lb. of copal to 1 gallon of spirits of wine containing about 95 per cent. of alcohol. The copal should be finely powdered, and may either be added to the shell-lac and spirit at the commencement, in which case the shell-lac should also be powdered, or the shell-lac may be first dissolved and the powdered copal then added; but in either case it is only the more soluble portion of the copal that is taken up, and the remainder settles to the bottom in a viscid mass from which the varnish may be decanted and strained for use. Copal may be added in the same manner to the white hard varnishes, and it is sometimes recommended to fuse the copal and drop it into water before attempting to dissolve it in spirit, but the advantage of adding copal to spirit varnishes is very questionable.

Lacker for brass like French polish is made in a great variety of ways, but the simplest and best pale lacker for works that do not require to be coloured, consists of shell-lac and spirits of wine only, in the proportions of about ½ lb. of the best pale shell-lac to 1 gallon of spirit. Lacker is required to be as clear and bright as possible; it is therefore always made without heat by continuous agitation for five or six hours. The lacker is then allowed to stand until the thicker portions are precipitated after which the clear supernatant fluid is poured off for use, and if this should not be sufficiently clear it is afterwards filtered through blotting paper into a bottle, which should be kept closely corked and out of the influence of light which would darken the colour of the lacker. This may however be easily prevented by pasting paper round the bottle.

Lackers are frequently required to be coloured to yellow, green or red tints. For yellow tints turmeric, cape aloes, saffron or gamboge are employed, for green, turmeric mixed with gamboge and for red tints annotto and dragon's blood; the proportions being varied according to the colour required. Thus, for a pale yellow, about 1 ounce of gamboge and 2 ounces of cape aloes are powdered and mixed with 1 lb. of shell-lac. For a full yellow, ½ lb. of turmeric and 2 ounces of gamboge, and for a red lacker, ½ lb. of dragon's blood and 1 lb. of annotto. The colour is also modified by that of the lac employed, the best pale or orange shell-lac being used for light coloured lackers and darker coloured shell-lac, or seed lac, for the darker tints. For pale lackers sandarac is sometimes used with the shell-lac. Thus a pale gold-coloured lacker is made with 8 ounces of shell-lac, 2 ounces of sandarac, 8 ounces of turmeric, 2 ounces of annotto, and ¼ ounce of dragon's blood to 1 gallon of spirits of wine. The most convenient method of colouring lackers, however, is to make a saturated solution in spirits of wine of each of the colouring matters, and to add the solutions in different proportions to the pale lacker according to the tint required, but the whole of the materials are not generally used by the same makers, and solutions of turmeric, gamboge, and dragon's blood afford sufficient choice for ordinary purposes. The turmeric gives a greenish yellow tint, and with the addition of a little gamboge, is generally employed in making the so called green lacker used for bronzed works.

Another mode of making lacker recommended by the late Mr. A. Ross, has 4 ounces of shell-lac and ¼ ounce of gamboge dissolved by agitation without heat in 24 ounces of pure pyro-acetic ether. The solution is allowed to stand until the gummy matters not taken up by the spirit subside, the clear liquor is then decanted, and when required for use is mixed with eight times its quantity of spirits of wine. In this case, the pyro-acetic ether is employed for dissolving the shell-lac in order to prevent any but the purely resinous portions from being taken up, a result almost certain to occur with ordinary spirits of wine, owing to the presence of water; but if the lacker were made entirely with pyro-acetic ether, the latter would evaporate too rapidly to allow time for the lacker to be equally applied.

Mastic varnish for painting, and similar purposes, is sometimes made in small quantities with spirits of wine; but more generally oil of turpentine is employed as the solvent, the proportion being about 3 lbs. of mastic to the gallon of turpentine. For the best varnish the mastic is carefully picked and dissolved by agitation without heat exactly as for the best white hard varnish, and after the mastic varnish has been strained it is poured into a bottle, which is loosely corked and exposed to the sun and air for a few weeks; this causes a precipitation from which the clear varnish may be poured off for use, but the longer the varnish is kept the better it becomes. Mastic varnish works very freely, but is liable to chill, and the surface frequently remains tacky for some time after the varnish is applied. To prevent the latter evil, it is recommended before dissolving the mastic to bruise it slightly with a muller, and to pick out all the pieces that are too soft to break readily, which may be used for common varnish. To prevent the chilling, which arises from the presence of moisture, Mr. W. Neil recommended a quart of river sand to be boiled with two ounces of pearlash; the sand is then to be washed three or four times with hot water and strained each time. The sand is afterwards to be dried in an oven and when at a good heat, half a pint of it is to be poured into each gallon of varnish and the vessel shaken well for five minutes, it is then allowed to settle, and carries down the moisture of the gum and turpentine with it. In making common varnish heat is generally employed to dissolve the mastic, and about one pint of turpentine varnish is added to every gallon.

Turpentine varnish is made with 4 lbs. of common resin dissolved in 1 gallon of oil of turpentine, and requires no other preparation than sufficient warmth to dissolve the resin; sometimes the resin and turpentine are mixed together in a stone or tin bottle, which is placed near the fire or in a sand bath over a stove, and shaken occasionally, but varnish makers generally mix the resin and turpentine in the gum-pot and employ sufficient heat to fuse the resin. This is a more expeditious practice, but is attended with some danger of fire. When a very pale turpentine varnish is required, bleached resin is used and care is taken not to employ more heat than is necessary in making the varnish. Turpentine varnish is

principally used for in-door painted works and common painted furniture, and toys. It is also frequently added to other varnishes to give them greater body, hardness and brilliancy.

Crystal varnish is a name frequently given to very pale varnishes employed for paper works, such as maps, coloured prints and drawings. A very good crystal varnish is made with 2 lbs. of mastic and 2 lbs. of damar, dissolved without heat in 1 gallon of turpentine. Another good but more expensive crystal varnish is made with equal quantities of Canada balsam and oil of turpentine. In making this it is only necessary to warm the Canada balsam until it is quite fluid, then add the turpentine and shake the mixture for a few minutes until the two are thoroughly incorporated; the varnish may then be placed in a moderately warm situation for a few hours, and will be ready for use on the following day. These crystal varnishes are nearly colourless, flow freely, and are moderately flexible, so as to bear bending or rolling, and either of them may be employed to make a tracing paper of middling quality, by applying a thin coat of varnish on one or both sides of any thin transparent paper, such as good tissue or foreign post paper.

Paper varnish, for paper hangings and similar purposes, is made with 4 lbs. of damar to 1 gallon of turpentine. The damar dissolves very readily in the turpentine, either with moderate agitation or a very gentle heat. Sometimes white or bleached resin is used instead of the damar, or the two are combined.

Water varnish.—All the varieties of lac may be dissolved in nearly boiling water by the addition of ammonia, borax, potash, or soda, but these alkalies all have the effect of rendering the colour of the lac much darker. The solutions may, however, be employed as varnishes which, when dried, will resist the application of water sufficiently well to bear washing, especially when the proportion of alkali employed is only just sufficient to cause the dissolution of the lac, which is also desirable in order to keep the varnish as light coloured as possible.—The least colour is given with diluted water of ammonia in the proportions of about 16 ounces of ordinary water of ammonia to 7 pints of water and 2 lbs. of pale shell-lac, to which about 4 ounces of gum arabic may be added. Borax

is, however, more generally used, and the proportions are then 2 lbs. of shell-lac, 6 ounces of borax, and 4 ounces of gum arabic to 1 gallon of water. When the varnish is required to be as light coloured as possible, white lac is employed.

Sealing-wax varnish, for coating parts of electrical machines and similar purposes, is made by dissolving $2\frac{1}{2}$ lbs. of good red sealing-wax and $1\frac{1}{2}$ lbs. of shell-lac in 1 gallon of spirits of wine.

Black varnish may be made with 3 lbs. of black sealing-wax and 1 lb. of shell-lac to the gallon of spirit, or fine lamp black may be mixed with brown hard varnish or lacker, according to the body required in the varnish. The interiors of telescope tubes are frequently blackened with a dull varnish of this kind, made by mixing lamp black with rather thick brass lacker, as little of the lamp black being employed as will serve to deaden the bright colour of the lacker. Mathematical instruments are sometimes blackened with a similar thin varnish, and the surface is afterwards brightened with one or two coats of lacker applied as usual. Ordinary lamp black, however, generally contains greasy impurities and moisture which render it unfit for varnish purposes, and therefore the best kind should be employed, or the lamp black should be purified by ramming it hard into a close vessel, and afterwards subjecting it to a red heat. In the workshop, when small quantities of lamp black are required, it is frequently made for the occasion, by placing a piece of sheet metal over the flame of a gas burner or of an oil lamp. A black varnish, sometimes used for metal works, is made by fusing 3 lbs. of Egyptian asphaltum, and when well dissolved, $\frac{1}{2}$ lb. of shell-lac and 1 gallon of turpentine are added.

SECT. II.—VARNISHING AND POLISHING WORKS IN WOOD. JAPANNING.

Upon all flat and upon most curved surfaces the varnishes are applied much in the same manner as paint, but with brushes that should be soft and scrupulously clean. The coats of the spirit varnishes are usually laid with camels' hair pencils and brushes of all sizes from one quarter to three quarters of an inch diameter, according to the dimensions of

the work; but for very large works flat camel hair brushes are usually necessary, although, from their comparative thinness, they require more frequent dipping in the varnish to keep them uniformly charged when employed in coating a large surface. The turpentine and oil varnishes require less delicacy in their application and are generally laid with ordinary painters' brushes, but sometimes with flat brushes made of softer finer bristles; all these bristle brushes, however, are rather harsh until partially worn away by use, when they work more smoothly, and owing to the adhesion of the varnish individual hairs are apt to loosen and come out.

The varnishes should all be uniformly applied in very thin coats, very sparingly upon the edges and angles, places where the fluid is always liable to accumulate; and a sufficient interval of time should be allowed between every coat for the perfect evaporation of the solvent, whether alcohol, turpentine or oil. The time required depends partly on the kind of varnish employed, and partly on the state of the atmosphere; but, under ordinary circumstances, spirit varnishes generally require from two to three hours between every coat. Most turpentine varnishes require six or eight hours, and oil varnishes still longer,—sometimes as much as twenty-four hours. But whatever time may be required, the second layer should never be added until the first is permanently hard, as when one layer is defended from the air by a second, its drying is almost entirely stopped and it remains soft and adhesive. Every precaution should also be taken to prevent any dust, or loose hairs from the brush, becoming accidentally attached to the varnish; should this occur, they must be immediately removed before the varnish dries, otherwise they will require to be carefully picked out with the point of a pen-knife, and the surface of the varnish levelled with fine glass paper, prior to the application of the next coat.

In the application of the spirit varnishes it is of the first importance that the varnishing should be carried on in a dry atmosphere; necessary for the following reason. In all alcoholic solutions of gum or resins, the gum is instantly precipitated by the addition of water, and not only by actual water but by its vapour, which latter is at all times more or less deposited by a damp atmosphere when at a reduced tempera-

ture in the form of an invisible dew. Such atmospheric moisture attacks and precipitates the gum or resin in the thin coat of varnish as that is laid on the work before it has time to dry, and gives its surface a milky, opaque or cloudy appearance, and the varnish is then said to be chilled, an effect which is even sometimes produced on a warm and apparently dry summer day when the air happens to be more than usually charged with moisture. This is a frequent difficulty, and is only to be obviated by carrying on the process in a room sufficiently warmed to keep the moisture suspended in the air, until the solvent has entirely evaporated and left the resin as a thin glassy coat but little altered, in a chemical point of view, from its primary state of fragment, flake, or grain, and entirely unacted upon by water, upon which circumstance the brilliancy and defensive value of the varnish depends. Not only should the room be sufficiently heated but all currents of cold air must be avoided, as cold draughts from the interstices of the door or window, if suffered to pass over the recently coated surface, are quite sufficient to dull the varnish wherever they extend. When the varnish has been chilled, its brilliancy and clearness may frequently be restored by giving the chilled surface another thin coat of varnish, taking care to avoid the causes of the former failure, and immediately holding the varnished surface at a moderate distance from a fire, so as to warm it sufficiently to partially re-dissolve the chilled coat; but care is necessary to avoid heating the varnish so much as to raise blisters, which would spoil the surface, and no remedy would remain but to remove the entire coat of varnish with glass paper, and recommence the process. The temperature generally preferred for the varnishing room, is about 72° F., but a few degrees more or less are not very important. The works to be varnished should be first kept in the room for a few hours that they may acquire the same temperature as the atmosphere, and the surfaces should be smoothed with fine glass paper, to remove all traces of moisture or grease, and if it should be necessary to stop any minute holes in the wood before varnishing, it should be done with some of the gums, with wax, or with something which contains neither oil nor grease.

An ordinary gallipot is frequently used for containing the

varnish and is sufficiently suitable; but it is desirable to have a wire or string fixed across the top for reducing the quantity taken up by the brush, which is wiped against the wire every time that it is dipped into the varnish. The quantity poured into the jar should be sufficient to nearly cover the hairs of the brush, in order to keep it soft. Too small a quantity of varnish is liable to thicken rapidly by evaporation, which should at all times be prevented, so far as possible, by keeping the vessel closely covered when not actually in use. Should the varnish, however, become too thick, it may be readily thinned by the addition of spirits of wine, and for good work it is more desirable to apply an increased number of thin coats than to use the varnish when too thick, as the surface is then almost certain to appear irregular and full of lines.

In applying spirit varnish some little tact and expedition are necessary to spread the coat uniformly before it becomes too much thickened by evaporation, or it will exhibit a very irregular surface when finished. If the surface does not exceed a few inches square no material difficulty is experienced, as the whole may be brushed over two or three times before the varnish becomes too thick; but those containing two or three square feet present much greater difficulty, as it is necessary that the varnish should be sufficiently worked with the brush to exclude all minute air-bubbles, which would spoil the appearance of the result, and can seldom be entirely removed until just before the varnish is becoming too thick to *flow* or spread uniformly after the brush has passed over it.

In first placing the brush on the surface it should be applied, not close to the edge, which would be liable to give too thick a coat at that part, but at a little distance from it, and the brush should be traversed towards the ends alternately with steady rapid strokes and only very moderate pressure. If the surface be small the whole may be passed over at the one operation, and then the brush may be returned to the edge at which it was first commenced, and it may be passed over the surface in the same manner a second or third time to distribute the varnish uniformly and work out the air-bubbles. Sometimes, in small surfaces, the second series of strokes is made at right angles to the first in order to distribute the varnish more equally, and the third is laid on in the same

direction as the first; but unless this is done expeditiously and equally, it leaves cross lines which injure the appearance of the work. Large surfaces are more difficult, as the varnish thickens too rapidly to allow of the entire surface being covered at one operation; they must therefore either be worked gradually from the one edge to the other, as in laying a tint of water-colour, or the varnish must be applied upon separate portions successively; but it is rather difficult to join the different portions without leaving irregular marks. It may, however, be successfully executed by thinning off the edges of the first pieces, and allowing the adjoining portion to overlap also by thinning off the edge with light strokes of the brush, made in the same direction as those on the finished portion; but some care is required to avoid disturbing the former coat while it is still soft and easily acted upon by the fresh varnish. In like manner, in laying on a second or any subsequent coat of varnish, care must be taken not to continue the application of the brush for a sufficient length of time to disturb the previous coat which is speedily softened by the fresh varnish, and if the application of the brush were continued too long, it would be disturbed and give the work an irregular or chilled appearance.

Wood and other porous surfaces absorb a considerable portion of the first coat of varnish, which sinks in deeper at the softer parts and raises the grain of the wood in a slight degree; a second coat is generally necessary to fill up the pores uniformly, and sometimes even a third is required. The work is then rubbed smooth with fine glass paper, and if the varnish is not to be polished, two or three additional coats generally suffice to finish the work, as the thickness of varnish should not be too great or it is liable to crack or chip.

With the view of economising the material, porous surfaces, such as wood and paper, are frequently sized over to prevent the varnish from sinking into the surface. For dark coloured works thin size made from ordinary glue of good quality, is generally used; but for light coloured surfaces, a lighter coloured size is employed, which is prepared by boiling white leather or parchment-cuttings in water for a few hours, or until they form a thin jelly-like substance, which is used in the tepid state, and sometimes solutions of isinglass or tragacanth

are used in like manner. For wood the choice, except as to colour, is nearly immaterial, the object being only to prevent the absorption of the varnish by a very thin coat of some substance not soluble therein; but for paper works the parchment size is on the whole preferable, as it is almost colourless and tolerably flexible. It is better in all cases to use two coats of thin size than one of a thicker consistency, as the size is then more uniformly spread and there is less risk of any small spots being left untouched, which would show specks in the varnish when completed; but no greater thickness of size should be employed than is absolutely necessary, or otherwise it would be liable to crack and peel off. Some kind of filling such as dry crushed whiting passed through a sieve, for light coloured woods and common mahogany, or rottenstone powder for darker woods, is frequently used on inferior works to fill the open pores of the wood previously to the application of the size or varnish and in French polishing: the powder is plentifully sprinkled over the surface of the work after the final glass papering and well rubbed in with the glass paper and rubber just previously used, the residue is then wiped from the surface and not dusted off, so as to leave the pores filled, and the sizing or varnishing then follows. The methods followed for polishing the best varnished works have been already described in the Catalogue, article VARNISHED WORKS.

Ornamental painting on varnished works is executed as mentioned in the same article, after the general surface has received a ground of about six coats of varnish, and been rubbed smooth and level. The colours used should be of the best quality, ground as fine as possible with turpentine, and mixed to the proper consistence with the same varnish as that employed for the general surface. So far as convenient the transparent colours are to be preferred and those principally used are dragon's blood, lakes, Prussian blue, chrome yellow, verdigris, white lead, lamp black and ivory black. Tincture of saffron is also employed for yellow colours, and also for staining the general surface of a yellow tint before it is varnished; the tincture is made by macerating half an ounce of saffron for two or three days in a pint of spirits of wine; other coloured stains are sometimes prepared and used in the same way.

Turpentine and oil varnishes are applied in the same general manner as the spirit varnishes, but as they dry more slowly, more time may be occupied in laying on the varnish and, therefore, large surfaces are more easily and uniformly covered; but the same precautions with respect to the dryness and warmth of the atmosphere are likewise desirable when it is required to produce a brilliant surface. In conclusion, it may be observed that, generally speaking, all coloured works are first painted of the desired tints, and a transparent varnish is afterwards laid on to give the required brilliancy, but for delicate ornamental painting two or three coats of varnish are generally laid on and smoothed down after the general ground has been painted, in order to prepare a suitable surface for the more artistic works.

Hardwood lacker, or polish, is applied to turned works as follows. The work having been turned and left as clean and smooth as possible from the tool, is then further smoothed with fine glass paper or with its own shavings, used in the careful manner described in the Catalogue under the head Woods, article 1; after which all dust remaining from the glass papering, is removed by rubbing the revolving work with a soft rag. A thin rubber is then made of three or four thicknesses of soft linen rag laid over each other, or of two thicknesses enclosing a ball of cotton wool about the size of a hazel nut, and a few drops of the lacker are placed on the center of the rag, either by a brush or by covering the mouth of the bottle with the rubber and shaking them together; a single thickness of rag is then put over the lacker, and a drop or two of linseed oil is placed on the external rag immediately above the lacker.

The rubber thus prepared is then applied with light friction over the entire surface of the work gently revolving in the lathe, never allowing the hand or the mandrel to remain still for an instant, so as to spread the lacker as evenly as possible, especially at the commencement, paying particular attention to all internal angles to prevent deficiency or excess at such parts. The oil is necessary because it, to some extent, retards the evaporation of the spirit from the lacker and allows more

time for the process; it also lessens the friction of the work against the tender gum percolating through the rag of the rubber. When the latter appears to be nearly dry, a second, third and even further quantities of lacker are applied in the same manner, sometimes towards the end with a new piece of external rag, and throughout these repetitions more careful attention can then be paid to any portions that appear to have been at all slighted in the earlier stages. There is moreover always some liability in thus polishing both the surface and cylindrical portions of the revolving work, for the lacker to slightly accumulate and to form concentric rings at irregular intervals upon them, which, if not counteracted, are plainly visible and destroy the uniformity of the polished surface; the formation of such inequalities, however, is readily and entirely prevented by frequently arresting the revolution of the work and then using the rubber lengthwise upon cylinders and diametrically across surfaces, whether curved or flat, in alternation with the polishing given when the work is in revolution, a precaution indeed which should never be omitted. After but little practice the entire process will be found both expeditious and facile in accomplishment, but when convenient, it is always desirable to repeat it after the expiration of a few days, by which time the lacker is frequently partly absorbed, especially in the end way of the grain, which latter being more porous should always receive a larger proportion of lacker at the first application.

Again, when a satisfactory, sufficiently thick and uniform coat has been attained by this repetition, portions of the work will often become cloudy after the lapse of about 24 hours, an effect more usual upon surfaces, due to some remains of the oil used that have mixed with the lacker now escaping through the coat of gum. In such case the work, which it is always wise to leave in the chuck in view of this probability, is returned to the lathe and repolished with a little spirits of wine, only, on a new clean rubber; this immediately removes all traces of the oil and leaves the surface permanently brilliant, but this *spiriting off* has to be executed with a light hand and continued only long enough to remove the oil, otherwise the spirit will redissolve and remove some of the yet tender coat of lacker. Many practical details on all points in the

preparation of the work and upon lackering and otherwise polishing turned works in the hard and soft woods are given pages 469—475, Vol. IV. to which the reader is referred, but it may be mentioned here that the rubbers made of a soft ball of cotton wool, as lately described, are very generally convenient as containing a larger supply of lacker which may be forced through the rag by squeezing the ball between the fingers to replenish the surface of the rubber whenever that commences to become dry or *tacky*. The outer piece of rag is thrown away after use, but the rubbers themselves will remain serviceable for several days if put away in any air-tight tin box immediately after use.

For common works, the lacker and oil are frequently both placed on the same surface of the rag. In this case the oil is first applied and then the lacker added; but, although more rapid, this method produces a far less even polish than when the lacker on the rubber is covered with a single thickness of oiled rag through which the clearer portions alone penetrate.

French polishing is effected after the same general manner as the lackering of turned works in hard wood; for, as previously mentioned, the only difference between French polish and hard wood lacker is that the former contains a larger proportion of spirit; adopted principally that the French polish may spread more easily and dry less rapidly upon flat surfaces, which are generally larger than those in turned works and, therefore, require more time in polishing, especially as there is no revolution of the work and the friction is derived exclusively from the motions of the hands.

The rubbers used are made in some variety of ways according to the views of the operators, the size is always proportioned to that of the work, but they seldom exceed three inches in diameter. The small cloth or list rubbers described in the Catalogue under the head of RUBBERS, article 5, are very generally employed for French polishing, especially for laying on the first coats, and it is preferred that the list should be torn off the cloth which renders the edge softer than if it were cut. In charging the rubber it is sometimes covered with a piece of rag upon which the polish is applied; at other times this linen rag is omitted and the face of the roll of list is itself saturated with the polish, in order to soften that which may remain

therein from previous use and the excess is squeezed out before commencing the polishing; these rubbers often serve for several months use, kept in an airtight receptacle between their periods of service. At the opposite extreme of durability are the little wool or wadding rubbers, RUBBERS, article 6, which are thrown away after a few minutes use; many operators consider this so wasteful both of wool and polish, that they adopt a medium course that permits the use of one rubber for five or six hours. For this, the wadding is first carefully picked to loosen it and remove any knotty pieces, and is then thoroughly saturated with the polish and squeezed moderately dry, so as to leave a sufficient quantity proportioned to the size of the work. The wet ball is then placed in the middle of a piece of soft linen rag, which is gathered up at the back and tied, and this rubber is replenished from time to time on the surface of the rag. A piece of sponge is sometimes used in the same manner and forms a durable rubber, but it requires to be softened every time before use in the same manner as the list rubbers. The choice, however, depends principally upon habit, and is nearly immaterial provided the rubber be moderately soft and contains a sufficient quantity of the polish to allow of that being gradually supplied to the work as the polishing progresses; but it is in all cases necessary that the rubber should be covered with a soft piece of rag moistened with a few drops of linseed oil, which must be renewed as often as it becomes so far clogged up as to prevent the polish passing freely through it, or when any portion of the polish on the surface of the rag has become so hard from the friction and evaporation as to be likely to scratch or disturb the half dry and tender polish transferred from the rubber to the work.

The work having been thoroughly smoothed with fine glass paper wrapped around a block of cork or wood, and the dust rubbed and wiped away with a clean cloth, the French polishing is commenced with free, continuous and uniform circular strokes, applied with very light pressure and gradually traversed over the entire surface; the same process is then continually repeated varying the positions of the strokes as much as possible, but keeping them about the same size, and taking care that every portion of the surface receives an equal

but not excessive quantity of the polish, which is regulated partly by the degree of pressure on the rubber and partly by squeezing the latter between the fingers. The principal points of careful attention are, that the pressure be moderate and uniform, that the circular strokes are taken regularly over the whole surface, and that the rubber be never allowed to remain a moment stationary on the work or to be *lifted* directly from it. Should the pressure be too great it is liable to disturb the smooth surface of the, as yet, tender polish or lacker already applied, and should the pressure or the strokes be irregular, a thicker coat of polish would be given at some parts than at others. Should the rubber be allowed to remain stationary on the work it would be liable to adhere to the surface, which would be injured on its removal; and the same result is more certain, if the rubber be lifted directly from it and, therefore, when removing the rubber it is always slid off at the sides or ends of the work, but if taken from the middle, it must then be done with a sweeping stroke so as to lift it gradually whilst in motion. Circular instead of straight strokes are employed, partly because they more quickly and uniformly fill up the grain of the wood, but principally to avoid the blemishes which would otherwise occur at the end of every stroke, if taken backwards and forwards, unless the rubber were every time traversed entirely off the end of the work, which would not only consume more time but is also not generally convenient.

The process is steadily continued without hurry until the grain of the wood appears to be thoroughly filled up, and the surface exhibits a uniform appearance, well covered with a thin coat of the gum of the polish. The work is then allowed to stand for a few hours to become hard, after which it is carefully rubbed with very fine glass paper, which should be wrapped around a flat cork or wood rubber, to smooth down all risings of the grain of the wood and any irregularities in the thickness of the coat of polish itself. The polishing is then repeated, and if it should be found desirable the work is again smoothed, and the polishing is then persevered in until the surface acquires a perfectly uniform, thin and tolerably bright coat of the gum. This when attained will nevertheless show cloudy marks owing to the presence of the oil used on

the rubber, and these are finally removed with a few drops of spirits of wine applied on a clean rubber, kept for the purpose, covered with a piece of clean soft linen rag. In this spiriting off the work is rubbed with very little pressure, first with the usual circular strokes and then, when the surface appears nearly dry, with straight strokes taken in the direction of the grain of the wood and traversed entirely off at the ends of the work; and this is continued until both rubber and work are quite dry, when the polishing will be complete. It should however be said that the polish will often be partly absorbed by the wood, especially by those of more open grain, after the lapse of a few days; it then becomes necessary to repeat the process as regards the last coat, first very slightly rubbing down the previous last coat with very fine nearly worn out glass paper, as it is essential to a smooth and durable surface that the ultimate layer or body of polish should be as thin as possible.

Intricate portions of carved works which cannot be polished with the rubber as explained for surfaces, are coated with white or brown hard varnishes applied with flat or round camel hair brushes, much after the manner of paint; but the quantity or body of varnish should be as thin as it is possible to lay on for any one coat, especially in the angles and about the edges, otherwise the character and beauty of delicate works is greatly deteriorated. White is in some cases necessary, but the brown hard varnish used for the darker woods is much tougher and, from its lesser transparency, it does not require quite so much care in use. The best results in this varnish polishing upon carved works are obtained by carefully painting on several consecutive coats, each of no more varnish than will just suffice to cover the work, each allowed to dry thoroughly hard and then carefully rubbed down with fine glass paper before applying the next; varnish of its usual density is employed for the first one or two coats to fill the pores of the wood and obtain a good body, but for all subsequent it is gradually more and more diluted with spirits of wine, until for the last it is of less than half its first strength.

The woods are frequently stained to other than their natural colours or to black, before they are polished or varnished and

which is perhaps more important, especially in cabinet and furniture works built up of several pieces of the same kind of wood, some of which pieces will nevertheless often prove to be lighter in their natural colour than the remainder, such lighter coloured portions are very generally darkened to agree in tone with their surroundings prior to the whole being polished. This portion of the subject need not be further pursued here, as pages 571—575, Vol. IV., give the composition of the stains used, together with particulars as to their application.

Japanning on metal, wood and paper, is executed much after the manner of varnishing, except that every coat of colour or varnish is dried by placing the object in an oven or chamber called a stove, heated by flues to as high a temperature as can safely be employed without injuring the work or causing the varnish to run or blister. For ornamental works, the colours ordinarily employed by artists are used; they are ground in linseed oil or turpentine, and are afterwards brought to a proper consistence for working by mixing them with copal or animé varnish. The latter is generally used as it dries quicker and is less expensive than copal varnish.

Black japanned works receive a first coat or ground composed of ivory or bone black pigment mixed in dark coloured animé varnish, and rather thickly, that it may have but little flow or run when laid with the brush on the surface, and this is employed to give a blacker tone to the japan subsequently used. The work after being dried in the stove then receives some three or four coats of the black japan, a semi-viscid fluid made of asphaltum with some pitch, dissolved with heat in a mixture of naphtha and turpentine, also laid on with a brush, the work being baked in the stove for several hours after every coat and then cooled before applying the next. When the surfaces have to be polished, as for the best works, from five to ten separate coats are required to obtain a sufficient thickness, with some rubbing down with powdered pumice stone on thick cloth or flannel between every two or three. The final coa: is polished, first, with rottenstone powder and oil on soft flannel and then with the same rubbed on with the hand

alone, in which last stage women are found to excel from the softer texture of the skin.

The clear japan made from brown asphaltum, sometimes mixed with umber and redder pigments to vary its tint, is alone used for plain brown japanned work. After one or two coats the surface is sometimes marked all over with a darker coloured mixture dabbed or spotted on with a brush or, for imitating malacca or bamboo, the darker tones are lightly wiped on with a cloth to partially blend with the ground colour whilst that is still moist, and the object is then baked prior to receiving a final coat of the clear brown japan, or of a lighter or transparent varnish, and again baked; these works are rarely polished.

Generally however no japan is used for coloured works, but they are painted with the ordinary painter's colours, ground with linseed oil or turpentine, and mixed with animé varnish; and the work is dried in the oven in the same manner as the black japan. To protect the colours and give brilliancy and durability to the surface, the work is afterwards varnished with copal or animé varnish made without driers. Two or three coats of varnish suffice for ordinary works, and five or six for the best works that are polished. Very pale varnish is required for light colours. Ornamental devices are painted on the objects in the usual manner, after the general colour of the ground has been laid on. The colours are then dried in the stove, and the work is finally varnished and polished just the same as if of plain colours, but with more care.

Metal works require no other preparation than cleaning with turpentine to free them from grease or oil, unless the latter should happen to be linseed oil, in which case the cleaning may be generally dispensed with, and the articles are placed in the stove and heated until the oil is baked quite hard.

Wood that is intended to be used for the best japanned work requires to be thoroughly well dried before it is made up, otherwise it would be subject to all the evils of shrinking, warping and splitting when exposed to the heat of the stove. To avoid these, the wood, after having been well seasoned in the usual manner by exposure to the air, is sawn out nearly to the required forms and baked for several days in the japanner's stove, the heat of which is gradually increased, and the wood

is then worked up into chairs, tables, trays, etc., which are afterwards again exposed to the heat of the stove, and any cracks or other imperfections that may be thus rendered apparent are carefully stopped with putty or white lead before the japanning is commenced. Common works in wood, said to be japanned, are, however, not stoved but only painted either in varnish or with common oil paint, and afterwards coated with either animé or turpentine varnish according to quality. In the same manner iron work for common purposes is frequently coated with black paint, brunswick-black, or black japan, applied without heat, and either varnished or not, according to circumstances, but all these expedients are greatly inferior to japanning.

SECT. III.—LACKERING WORKS IN METAL. BRONZING.

In lackering brass and other metals, the work requires to be perfectly cleaned from all grease or oil, the presence of which would prevent the adhesion of the lacker, usually the metal is heated nearly to the temperature of boiling water, that the spirit may be rapidly evaporated from the lacker to prevent any risk of its being chilled by the moisture of the atmosphere condensing on the cold metal. The heat also causes the lacker to attach itself more firmly to the metal, and from the readiness with which it flows the lacker then appears much more brilliant. The heating is, however, not imperative, as metal may be lackered in the same manner that spirit varnish is applied to wood, but a dry and warm atmosphere is then essential; or the lackering may be carried on in bright sunshine, but there is greater liability of the adhesion of dust owing to the lacker drying less rapidly, and on the whole the process is not so successful as when heat is applied.

Lackering metals should follow immediately after their polishing, or if it must necessarily be delayed, the work should be thoroughly coated with clean oil, or immersed in very pure water, in order to retard the tarnishing, which will nevertheless occur in water after the lapse of a few hours; with oil the polish is preserved much longer. Works having ornamented surfaces from which the oil could not readily be cleaned, are sometimes closely wrapped in cloths in order to

exclude the air as much as possible, but the sooner brass is lackered after polishing the more brilliant it will appear. The works polished with oil are carefully wiped before they are heated, first with moslings, and afterwards with whiting, applied either with a rag or a brush, so as thoroughly to remove all traces of grease; those polished with water merely require to be wiped with a clean cloth, and those finished by the dipping processes are generally dried in saw-dust, afterwards dusted or wiped off.

The work is heated prior to lackering in a variety of ways. In manufactories devoted principally to brass works, there is generally a lackering stove having a broad flat top upon which the work is laid completely out of reach of the dust or smoke from the fire. In some instances a circular row of gas flames is employed, as in gas stoves, for heating a plate supported on four legs like a table; this method is very clean and appropriate for small works. In the absence of either of these a charcoal fire covered with an iron plate is commonly used, and another very clean and convenient method is to make the end of a flat bar of iron red hot and to pinch the bar in the vice, placing the work at some distance from the heated extremity and gradually advancing it as the bar cools.

Vessels filled with boiling water or steam are sometimes employed; these are very cleanly and suitable, as there is no risk of excess of heat. Tubes are sometimes heated for lackering by filling them with boiling water, the ends being temporarily stopped with corks. The tubes of brass bedsteads are sometimes supported against an india rubber pad which closes one end, and are held at the other by the inserted nozzle of a steam jet surrounded by a similar rubber pad to seal the tube and retain the steam during the lackering. Small works not having many holes are sometimes dipped into clean boiling water, the principal portion of which is shaken off when the work is removed and the remainder speedily evaporates. In lackering the heads of a large number of small screws, they are frequently all inserted in a piece of card which is heated over a charcoal fire or a gas flame, and the whole are lackered at one process. In thin circular works, the friction of polishing in the lathe frequently suffices to give the requisite heat, if the lacker be applied immediately.

In whichsoever way the heat is applied the temperature of boiling water should not be exceeded, as excess of heat is liable to discolour the work by oxidation before it is lackered, for which there is no remedy but repolishing; or if this evil does not occur, the heat may evaporate the spirit so rapidly as not to allow time for laying the lacker on evenly; or it may be sufficient to cause the boiling of the lacker, and in this case the surface will present small dots caused by the bubbling of the spirit. Should failure arise from one of these causes, the lacker may be removed for another trial by wiping off the first coat while it is still warm with a rag moistened with spirits of wine, but to remove lacker after it has become hard it is generally necessary either to apply emery paper or to boil the work in a ley of pearlash and water, the latter is preferred, as unlike the emery paper, it does not deteriorate the angles or surfaces of the finished form. After the work has been heated it is wiped with a piece of clean rag and it should not afterwards be touched with the fingers which might communicate some trifling grease or dirt, but the temperature is generally sufficient to prevent the application of the naked hand; advantage is therefore taken of any small hole that may happen to be in the work, and a screw tap, a broach, or an arbor is inserted to serve as a handle.

For flat works the lacker is applied in much the same manner as spirit varnishes are laid on flat surfaces, but owing to the employment of heat the lacker sets much more rapidly, and as only a very thin coating is required the process is generally completed at one operation. Some care and expedition are therefore necessary to lay the lacker uniformly on the work, but being thinner than spirit varnish it flows more freely and does not require to be worked to expel air bubbles. The lackering is generally commenced at one edge of the work, and the strokes of the brush are taken in parallel lines from side to side; the surface usually receives two coats of lacker in immediate succession, and when the works are small the first coat is always completed before the second is commenced, but in large surfaces the two are sometimes carried on simultaneously, the first being a small distance in advance; but this requires to be done expeditiously, otherwise the extreme edge of each coat will be liable to dry while the other

is in progress, and the surface when finished will show streaks wherever this has occurred; it is therefore the better practice to continue the first coat entirely over the whole surface at the one operation, and if necessary the metal may be reheated for the second.

The difficulties in lackering large surfaces rapidly increase with their dimensions; thin flat plates are frequently required to be lackered on one face only, in which case they are conveniently manipulated supported on one long edge and nearly vertically; large sheets of brass, some seven feet by three feet, are lackered in the author's workshops in this manner. Using a flat camel hair brush, from 2 to 3 inches wide, the operator traverses the plate in parallel horizontal lines, commencing at the top and allowing the margin of the second stroke to just overlap that of the preceding and so on to the bottom, an assistant applying the heat to the unlackered side by the wide flame of a gas blow-pipe which he traverses in agreement with the movements given to the brush on the other; a single full coat of lacker may be given in this manner or, which is better, the work may receive two thinner coats one after the other. Expedition without hurry is essential, and as the brush has to be replenished several times in the course of every long traverse, the evenly lackered surface is a good example of difficulty overcome by individual dexterity and practice.

Success in all lackering depends, however, very much upon the good condition of the brush and its being kept uniformly moistened with the lacker. Camel hair brushes are always used, those of about one quarter of an inch diameter are employed for small works, and larger round or flat brushes for those of greater size. They should always be kept quite clean and soft. When the lacker is in frequent use, it is generally kept in a small bottle, the cork of which is perforated to fit the handle of the brush, which is thus suspended just above the lacker when not in service; in this manner the brush may be kept in tolerable condition for some time. If however the brush is only employed occasionally, it is a better practice to wipe it as dry as possible on a clean rag after use, and immediately wash it in a little clean spirits of wine, which may be added to the lacker to compensate for that lost by evaporation,

and the brush may then be laid by for future service. It must also be remembered that the heat of the work speedily thickens the lacker in the brush, which soon becomes stiffened and leaves streaks on the work. This inconvenience is frequently experienced in going over a single large surface; it is therefore a good method in lackering large works to dip the brush in clean spirits of wine, and wipe it, either against the edge of the vessel, or a central wire fixed across its mouth, before taking a fresh supply of lacker. Or if this be thought too troublesome, the brush should at any rate be dipped sufficiently deeply in the lacker to cover the hairs, and then be wiped against the cross wire to reduce the quantity and mingle the fresh lacker with that previously contained in the brush. The quantity of lacker taken in the brush depends greatly upon the experience of the operator; those who have had much practice are enabled to use the brush tolerably full of lacker, which under proper management flows freely over the surface; but those who have less experience, will be more likely to succeed when the brush is only moderately moistened, as any irregularities in its application are then less apparent.

Circular works are generally lackered in the lathe, and when the friction of polishing is not sufficient to give the necessary temperature, the arbors, screw chucks or other apparatus necessary for fixing the work in the lathe, are laid in order ready for use, after having been wiped clean with whiting as carefully as the work itself. The latter when sufficiently heated, is rapidly transferred to the lathe, finally wiped with a clean cloth, and lackered with a rather dry brush, which is gradually traversed along the work, while the lathe is slowly turned by the hand in the direction to lay the hairs straight. The brush should be traversed twice over every part of the work to ensure that being uniformly covered with the lacker, for should this not be the case the surfaces will frequently exhibit prismatic colours when examined from different points of view.

The lackers whether pale or coloured, are applied in the same manner to all works either plain or ornamented, but for mechanism the pale lackers are almost exclusively used; the coloured lackers are principally applied to works of an ornamental character, with the view of giving a richer tint

to the metal than it naturally possesses. In some instances the colour is produced entirely by the lacker, as on wood or leather, which are sometimes covered either with silver leaf or tin foil and afterwards coated with a gold-coloured lacker. This constitutes a sort of fictitious gilding that is tolerably durable, but which disappears on the application of alcohol or naphtha.

Ornamental works cast or stamped in brass for such purposes as portions of house furniture, lamp and gas fittings, trays, etc., the preparation of which is referred to in the Catalogue, Brass, article 9, as also other artistic productions, caskets, plaques, statuettes, etc., cast and chased in copper, gunmetal alloys and zinc, are generally all finally surface coloured by various processes of dipping and bronzing, some of which will be described.

The former and more extensively used variety of works are rendered bright and lustrous and of their natural colour, except so far as that is modified by the lacker subsequently placed upon them, or they are reduced to brown, green and other tints, afterwards coated and somewhat modified by the lacker, by *dipping*, a very simple process, as follows. After the various portions of the works have been fitted together and otherwise completed, the parts are annealed by heating to redness over an open fire and are then gradually cooled, the cooling protracted over one or two hours, or for a still longer period for such portions as have been brazed together. The heat effectually removes any grease or dirt the work may have acquired during its fitting, which is absolutely essential; but annealing is inadmissible with works that have been soft soldered as the heat would melt the solder, these portions, therefore, are annealed before they are soldered together and they are then boiled in a strong ley of pearlash and water to remove the grease.

The work is next pickled in a cleaning bath of dilute aquafortis, which may be made with two or three parts of water to one of acid; and an old bath that has been previously frequently used, and therefore contains a small quantity of copper in solution, is generally preferred. The work is allowed to

remain in the pickle for one or two hours according to the strength of the acid, but the metal must not be immersed for too long a time or it will be eaten into holes. The entire surface of the work is next scoured quite bright with sand and water, applied with an ordinary scrubbing brush; the work is then washed and allowed to remain in quite clean water for a few minutes until the dipping bath is ready.

The latter consists of pure nitrous acid, commonly known as dipping aquafortis, a sufficient quantity of which is poured into a glass or earthenware vessel to allow of the work being entirely covered, so far as the process is required to extend. If the work does not require to be wholly immersed, it is handled with the fingers, but if the entire surface is to be dipped, brass pliers are used, as the insertion of wood or iron instruments deteriorates the acid. The bath having been prepared, the work is taken out of the water and dipped into the aquafortis for an instant only; it is then quickly removed, plunged into clean water and well rinsed to remove the acid, for which purpose two or three vessels containing cold water and one hot water are arranged in order, and the work is transferred from one vessel to another as rapidly as possible, in order to prevent its being discoloured during its passage through the air. The more effectually to remove the acid, some manufacturers add argal to the hot water. If the work should not appear sufficiently bright it may be dipped a second time, but it must be quickly removed from the acid which acts very energetically on the metal, and the dipping must not be repeated too frequently or a bad colour will result, which can only be remedied by cleaning the surface a second time. Immediately after the rinsing the work is plunged into dry beech or box wood saw-dust and rubbed until quite dry. The work is then burnished on the parts required to be bright, and lackered with as little delay as possible to prevent discoloration; colourless, yellow, orange, red or green coloured lackers being used as it may be required to retain or modify the natural colour of the brass.

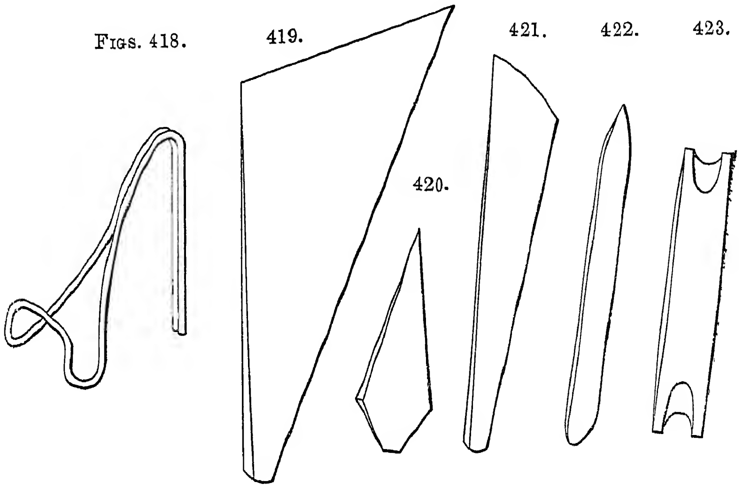
The brown, green and other colours imitating those that oxidation produces upon real bronze, when required for the class of work under consideration, are obtained after the final polishing by the application of chemical preparations from

which the surface of the metal acquires a uniform and fairly well attached film of colour which is rendered permanent and durable by the lackers subsequently placed upon it; at the same time this film tones or darkens the yellow, green or red lacker used, with just the reverse effect to that of the pure bright metal lately considered which shines through and brightens it. Success in all the methods of bronzing that follow, however, can only be obtained after the work has been rendered chemically clean from grease either by the dipping bath or with the file and emery paper or, in some cases, as for embossed and chased work, by boiling in a ley of potash and then scrubbing with clean sand and water: the results are also better when the surface of the work is not too highly polished but is left with a fine nearly imperceptible grain, which latter appears to act as a key to aid the uniform action of the chemical solutions, want of uniformity often resulting from a too high polish. It is also of the first importance that the work should never be touched with the fingers after it has been finally cleaned or polished, thenceforth throughout the process, avoided by holding it in loops of wire, small objects in those of the form of fig. 418, or in brass or copper tongs, or in others of wood made of two thin straight pieces joined at one end by a metal spring in the form of a pair of sugar tongs, which last it may be mentioned are always used in dyeing ivory for which a separate pair is kept for every colour. Earthenware or glass vessels, whenever possible, are preferable, and should be of sufficient capacity to allow the work complete immersion, especially desirable when the solutions are employed with heat, for should they so boil away as to expose any portion of the work, that, is usually immediately stained by its contact with the air; with weak solutions used hot, further small quantities are from time to time added to replace that lost by evaporation, with stronger, similar additions of the water or acid used are made to the same end, but also, which is more important, with the view of maintaining the fluid as nearly as may be of the same density throughout its application.

Two or three days immersion in good white vinegar gives copper or gunmetal a uniform dull Indian red colour and brass a dusky ochreish green. The addition of sal-ammoniac, in

the proportion of one to two ounces to a pint of vinegar, gives copper a deeper red and brass a more yellow green, with the time of immersion about one half, but if the solution be too strong the metals will show some corrosion. The work after immersion is very thoroughly rinsed in several waters, dried

FIGS. 418. 419. 420. 421. 422. 423.



by dabbing with a clean cloth or in sawdust, heated, and lackered with pale transparent lacker.

A mixture of one part strong nitric acid to sixteen of water, the metals immersed from 15 to 20 minutes, then well washed, dabbed nearly dry, and immediately subjected to a regular heat of about 200° Fahr. for about half an hour, gives copper a uniform pale chesnut and brass a delicate blue green bronze; the immersion causes little change of colour, which latter is gradually acquired and does not commence until the work has been heated some few minutes. It is essential, as with all such applications of heat in drying, that any accumulations of the water from the washing should be well dabbed off with a clean cloth before the heating, otherwise the evaporation of any drops that remain stains the surface. The heat may be given in a muffle, an iron tube placed in an open fire, the work supported within it in one of the loops, fig. 418, or some other form of wire stand, or, very conveniently for small objects, on a sheet iron plate over a good sized spirit lamp;

the work is finally rubbed with a bristle brush before reheating for lackering.

One part of a solution in the proportion of 1 ounce sal-ammoniac, 3 ounces cream of tartar and 6 ounces of common salt to 16 ounces of water, mixed with five parts of a solution of 1 ounce of nitrate of copper in 16 of water, with immersion for about half an hour, gives copper and gunmetal a full brown chestnut and a dull yellow olive green to brass. The same solutions and quantities, except with two instead of six parts of salt in the former, and immersion for about an hour, colours copper a uniform chocolâte and brass a dull olive green. The work is well washed when withdrawn, dabbed free of water, dried at a gentle heat, and allowed to stand one or two days before it is finally dry brushed before lackering.

A solution of half an ounce of corrosive sublimate in two ounces of glacial acetic acid with twelve of water, used heated to about 150° Fahr., with about 15 minutes immersion, leaves copper and gunmetal with a fine dark slate coloured efflorescence and when this has been brushed off after the work has been washed and dried, copper shows a deep purple chestnut and gunmetal a dark brown green, both excellent under lacker.

Quicker results are obtained by from three to four minutes immersion in solutions of bichloride of platinum, or by painting on with a brush, when the objects are small, and by dabbing on the liquid with a small mop made of pieces of rag tied to the end of a stick when they are large, this last method preventing the formation of streaks of unequal colour which will sometimes occur with strong and active solutions from the straight strokes of a brush. Bichloride of platinum diluted by twice its bulk of water gives copper a nearly black brown, and with from three to five parts of water, like but less dark colours. Gunmetal and brass acquire similar but sometimes less uniform results. The work is then dried, first by very gentle dabbing with a soft cloth, carefully avoiding rubbing which would remove some portion of the colour, and then in front of a fire or over a gas burner; when quite dry and cold it is lightly rubbed with a soft brush and a little black lead powder previously to the application of the green or other lacker, which modifies and also renders the colour quite per-

manent; the work throughout never being touched with the fingers.

Zinc acquires a uniform jet black by about 20 or 30 seconds immersion in any of the above bichloride of platinum solutions. By painting on, or with one to two minutes immersion in a mixture formed of 1 part of the bichloride in 8 parts of a solution in the proportion of 120 grains of verdigris to 12 drachms of glacial acetic acid in 8 ounces of water, zinc acquires a uniform dull copper colour which darkens to a very deep shade after some days exposure to the atmosphere; further dilution with water produces lighter tones. Works so treated are dabbed free of surplus moisture, dried at a very moderate heat and then rubbed with a soft dry brush; the black and the copper coloured bronze on zinc are suitable for lackering but are quite permanent without. Arsenic a far less expensive material, yields sure and in most respects better results. A solution of one ounce each of arsenious acid and sulphate of iron in four of hydrochloric acid, with ten minutes immersion, gives a uniform, deep steely black of slightly reddish tone to copper, gunmetal or brass, excellent as the basis for subsequent lackering. One part of the foregoing solution mixed with three parts of a solution of an ounce of oxalic acid in twenty of water, with 15 to 20 minutes immersion, colours copper and gunmetal a uniform and rather greenish blue, gunmetal being the greener, the colours, prior to lackering, appearing decided blues or bluish chestnut according to the angle at which the work is held to the light; if left unlackered for a few days the colours gradually darken to much deeper shades. All works treated with the foregoing solutions or any that contain hydrochloric acid require exceptionally plentiful washing to kill the cumulative action of this acid before they are dabbed and dried at a gentle heat.

Brass previously cleaned and polished, immersed from one to two hours in a mixture of one part each of pure nitric and sulphuric acids in eight of water, receives little change of colour, but becomes covered with innumerable uniformly disposed and interlaced minute specks, both brilliant and dark, analogous in character to those in avanturine; the work when washed and dried is heated and lackered without delay; the variegated surface is effective and, as with curled brass surfaces produced

as described in the Catalogue, Brass, article 5, is especially useful for works liable to be marked or scratched when in use.

In using any of the foregoing solutions or others to be mentioned, the metals, except zinc, are preferably first cleaned by leaving them for about twenty minutes in a dilute cleansing bath composed of one ounce each of nitric and sulphuric acids to every twelve of water, withdrawn from which in the tongs or wire loop and still held thereby, they are rinsed in clean water and then immersed, whilst everywhere wet, in the cold or hot acid solutions. They may then be lifted out from time to time for examination that so soon as the colour appears sufficiently developed they may be immediately well washed, still held in the tongs or wire, in clean water to arrest further action ; the work is then drained, dabbed and dried as already explained and after gentle brushing is ready for lackering. Some prefer, however, to omit the washing and plunge and dry small works in powdered blacklead, so as more gradually to stay the action of the fluids and avoid possible water evaporation stains, and the powder which adheres when the work is dry is gently brushed off to give a surface gloss; blacklead is often sprinkled over and brushed upon works that have been washed and dried for the same purpose, and always with those treated with arsenic and iron. Any moderate surface efflorescence from too protracted immersions may usually be removed by light brushing with oilstone or other fine powder, without detriment to the colour beneath; more generally employed cold, most of the solutions are far more active when used moderately warm and, in most cases, an insufficient depth of colour may be increased by a repetition of the process, but should such repetition be delayed for some hours it is then better to brush the work with oilstone powder or washed whiting before resorting to it.

The final result as to colour, it is evident, may be greatly varied by that of the ground obtained and that of the lacker used upon it. Pale lacker but little alters the tone of the ground and so on, more and more, through the deeper coloured to dark orange and green lackers; the last named, coloured with turmeric, is used for green bronze, which is varied as to depth of shade by the darker to nearly or quite black ground given to the work. The usual practice is to employ but one

or two deep coloured lackers, and to reduce small quantities of these to lighter tones by the addition of nearly colourless lackers for use as required. It should also be said that the quality of the metal has some influence on the tone of the ground obtained, so that it is sometimes rather difficult to make the colour of the ground precisely uniform throughout works composed partly of cast and partly of sheet metal, this is also sometimes felt in works entirely cast from inequalities in their density; but this difficulty is generally successfully overcome by variations in the solutions used or in the duration of their application by those practised in the art of bronzing, or, where permissible, far more readily, by first electrotyping the work that it may present one uniform coating of copper for subsequent treatment, a practice generally followed with the ordinary qualities of artistic French bronzes cast in zinc, which, when coloured, however, are not usually lackered.

A lackered surface is frequently undesirable, especially for objects of art, in such case the bronzing is effected either by chemicals, salts of other metals or sometimes vegetable acids, dissolved in acids or water, to produce a durable surface film a compound of the metal acted upon, or else by the acceleration of the natural oxidation of the metal itself, which can be obtained by very simple means. These processes are peculiar, inasmuch as natural oxidation, of which both partake, is progressive and cumulative as to thickness and depth of colour, but any film of oxide artificially produced, or those complicated by salts of other metals, appear to defend the surface of the metal from further action of the atmosphere so that, with some few exceptions, the colour once thus obtained remains permanent. The thorough cleansing and the avoidance of afterwards touching the surfaces to be bronzed until the process is completed is, perhaps, of still more importance than with work subsequently lackered. Works of moderate dimensions, therefore, are held and transferred in the metal or wood tongs, which implements themselves should always be scrupulously cleansed from the results upon them of any fluid in which they have been previously employed; smaller works,

very conveniently, in *round* wire loops, made of the *same* metal being treated, of the form of fig. 418, which they touch only at two or three points, by which loops also they may be suspended in the liquid from the rim of the vessel in which they are immersed or boiled, or stood within a muffle, on a hot plate or before a fire to heat or dry; objects too large for either of these methods are managed by means of wires bent or twisted around some prominent part and so arranged, if possible, that the wires may be removed whilst the work is immersed or dried. It should be repeated that, should the immersion be continued much beyond that necessary for the full development of the colour, the latter is sometimes liable to irregularities, which blemishes then usually become more pronounced the longer it is protracted; added to this, the film giving the colour is of inconsiderable substance, in which condition it is intimately attached to the surface, but it continuously thickens with lengthened immersion, and should the latter be too far prolonged it very frequently acquires independence and breaks up into small scales which exfoliate from the metal beneath.

Works in copper first cleaned in the dilute acid bath previously mentioned and then immersed four or five days in a solution of common salt, made in the proportion of two ounces to every quart of water, acquire a dull light red colour similar to that of the pigment so called and well known in the Cashmere embossed copperware, which film after washing and drying is permanent; and, as with most other preparations, the results are far better from a protracted immersion in a comparatively weak solution than by one of less time in a stronger. Brass by the same treatment receives a uniform but less useful ochreish grey. Rather fuller shades of like colours may be obtained by a similar time of immersion in good white vinegar or, as the best usually contains some sulphuric acid, better by immersion in a bath of three parts of glacial acetic acid in twenty-four of water; the work, as with all the foregoing, subsequently well washed, drained and dabbed free of all accumulations of water before drying in a warm atmosphere.

Copper previously acid cleaned, immersed from 10 to 15 minutes in a solution of one ounce of sulphate of iron to one

ounce of hydrochloric acid in two of water, the fluid maintained at a heat of about 180° Fahr., and the work then long washed in several waters, dabbed and dried before a fire, acquires a uniform lavender toned red brown bronze. Gun-metal with the same time a greenish brown, and brass a uniform dull light green of sage character, all of which colours perceptibly darken after some days exposure to the atmosphere. Similar treatment with the solution in the proportion of one ounce of the sulphate of iron to three each of the acid and water, bronzes copper to a very deep shade of the same colour, but is too corrosive for either gunmetal or brass.

Acetate of copper and hydrochloric acid, 40 grains of the former to every ounce of acid, with 10 to 15 minutes immersion, gives a full fawn buff to copper, that of some of the best French bronzes. After immediate thorough washing the work is allowed to remain some days in a good quantity of clean water, frequently changed; when dried it may be rendered lustrous by brushing with a small quantity of blacklead. A deep chesnut of decided purple tone, another of these bronzes, is given to copper by boiling for about five minutes in *French pickle*, composed of an ounce of acetate of copper, half an ounce of sal-ammoniac and one and a half ounces of acetic acid to every twelve ounces of water; an immersion of about half an hour in the same solution used cold produces similar results; acetic being far less active than hydrochloric acid; the work requires but ordinary washing and drying, with or without the blacklead polishing.

A mixture composed of six drachms of binoxalate of potash, (the ordinary salts of lemon used for taking out ink stains), 3 drachms of chloride of ammonia and 3 ounces of glacial acetic acid to every 30 ounces of water, employed hot at about 180° Fahr., the metals previously emery cleaned and subsequently drained and dried at a gentle heat, with about 20 minutes immersion, gives copper a mauve toned full buff, the colour of some French red buff bronzes, and gunmetal a dull olive green bronze. Brass immersed for about an hour acquires a uniform excellent dull sage green. The same solution previously used upon copper and then diluted with twice its bulk of water, used hot as before but with only 30 seconds immersion, gives zinc a permanent bronze indistinguishable

from copper, the surface of the metal quite unimpaired and the tone of colour the same as that given to copper by sulphate of iron and hydrochloric acid.

Copper, acid cleaned and immersed from two to three hours in perchloride of iron diluted by twice its bulk of water, then washed, dabbed and dried for a few minutes at a gentle heat or before a fire, acquires a permanent and beautifully regular chestnut colour, that of another variety of French bronze. Prolonged immersion deepens the tone, about four to five hours giving a very deep chestnut of purple tinge. Upon gun-metal, with rather more time, the colours are similar but usually less uniform, probably from the tin in this alloy, but this difficulty, as with the commercial French bronzes cast in zinc, is overcome by first electrotyping the object and then treating the uniform deposit of copper. Upon brass on the other hand the effect is as regular as upon copper but somewhat slower, about three hours produces a uniform olive green, four a deeper shade and ten a very dark green. Zinc immersed from 10 to 15 minutes in one part of the perchloride to four of water, receives a beautifully regular and permanent film of deep, green tinged black, the metal when washed, dried and brushed showing a lustre without any surface corrosion.

Copper cleansed in the dilute acid bath, and boiled for one hour in a solution of 200 grains each of acetate of copper and arsenious acid in two ounces of glacial acetic acid to every eight of water, then transferred wet and boiled for forty to fifty minutes in perchloride of iron diluted by four parts of water, washed, dabbed and dried in warm air, acquires a rich deep red chestnut bronze with purple reflections; but with these and generally with all solutions used hot, small quantities of water have to be frequently added to replace that lost by evaporation so as to maintain the fluids at about their original densities throughout the process. A valuable bronze of the deepest almost black chestnut is given to copper, previously acid cleansed, by ten or twelve hours immersion in a cold solution of two ounces of perchloride of iron with one of hydro-sulphate of soda in every four of water, washed, dabbed and warm air dried; the film of colour darkens after a few days exposure to the atmosphere.

Nitrate of copper in the proportion of an ounce of the

crystals to sixteen of water, a solution of perfect limpidity, used heated to about 180° Fahr., the metals emery cleaned, with immersion from 10 to 15 minutes, the work then washed, dabbed and dried, produces a uniform film of a dark fawn colour which gradually changes to a deep chocolate toned bronze. Brass acquires a buff green with a more protracted immersion of one to two hours, the colour as with copper becoming darker with exposure to the air. Additions to replace evaporation in this case are made with the solution and not with water.

Hazeline, an extract of the bark of the willow used in the pharmacopœia, produces very satisfactory results upon metals that are emery and not acid cleaned. Copper boiled for 20 to 30 minutes in the undiluted liquid acquires a red toned liver coloured suboxide, the colour of some French buff bronzes. The same treatment on gun metal produces a green, deep, old gold coloured buff, and on brass a very beautiful and uniform bright olive buff; zinc boiled for 4 or 5 minutes acquires a regular dense indigo toned black, the previously polished surfaces in all these metals being quite unimpaired. The works are immersed in shallow earthenware vessels so as to be but little more than covered, and small quantities of the hazeline are frequently added to the boiling fluid to maintain that at about the same level and concentration throughout; subsequently they are well washed, dabbed and when quite dry polished to a lustre with a bristle brush.

Other simple vegetable acid preparations are employed with good effect. An infusion of one ounce of fustic dust in sixteen of water, prepared at a gentle heat for about twenty-four hours, then filtered through flannel and used heated to about 180° Fahr., the metals emery cleaned, allowed to drain and dry and to stand a day before the fustic deposit is brushed off, bronzes copper after an hour's immersion to a bright golden chestnut, gunmetal to a bright old gold colour, and brass to a similar but much brighter gold. Zinc with fifteen minutes immersion acquires a beautifully delicate sea green.

Copper acid cleaned and washed previously to being boiled for four or five hours in a plentiful supply of common green water, then drained and dried, acquires a uniform light red toned golden chestnut bronze, a useful colour which becomes a

little darker with exposure to air. The infusion is made from the dark coloured portions of the leaves of cabbage or similar vegetable, chopped and packed close, simmered for a day in just sufficient water to cover them and the strained off water evaporated to about half its bulk before use. Boiling emery cleaned copper about 40 minutes in a solution of half an ounce of permanganate of potash to every 16 of water, then washing in hot water, draining and drying, produces finally a similar, but duller and browner bronze; the depth of colour in either of the above not much exceeding that of the natural red suboxide.

A solution of indigo paste, a preparation sold by the drysalters, in the proportion of one ounce of the paste dissolved in sixteen of water, 13 parts, mixed with 3 parts of hydrochloric acid, and used at about 180° Fahr.; the metals acid cleaned, well washed in hot water before and after immersion in the indigo and then allowed to drain and dry, with about 40 minutes immersion, bronzes copper to a red brown of the ordinary tea urn colour, gunmetal to a deep olive green buff, and brass to a light but dusky sage green.

An infusion of one ounce of logwood dust in twenty ounces of water, prepared and filtered as described for fustic and used heated to about 180° Fahr., the metals emery cleaned and washed and allowed to drain and dry after treatment, with 30 to 40 minutes immersion, gives copper a deep bright red puce coloured bronze, and gunmetal and brass similar colours of rather browner tone, all of which somewhat darken after a few days' exposure to air. If the metals be acid cleaned and then thoroughly well washed in hot water immediately before and after their immersion in the logwood decoction, the colours are perhaps more useful, far deeper purples inclining to black, similar to those of the darker Florentine bronzes.

Excellent results are obtained by boiling in ordinary writing ink, that prepared by Field of London diluted by about one twelfth part of water being used by the author; the work emery cleaned, and after boiling immediately well washed in hot water before being drained and dried at a gentle heat, and then allowed to remain some twenty-four hours before the efflorescence is brushed off. Copper boiled for one hour acquires a full liver coloured buff bronze, gunmetal a deep olive green brown,

and brass a dark dull olive green. Zinc immersed for two minutes receives a uniform and very dark green slate colour. A little olive oil rubbed over the work after it is dried and brushed and then rubbed off after a few days, improves the lustre of ink bronzed metals, a practice generally admissible with most other unlackered modes of bronzing.

Zinc previously emery cleaned, immersed from one to two minutes in bichloride of platinum diluted with from 8 to 12 times its bulk of a solution composed of 120 grains of acetate of copper and 12 drachms of glacial acetic acid to every 4 ounces of water, immediately well washed, dabbed and dried near a fire, receives a permanent uniform film of dull red brown, undistinguishable from copper oxide and more or less dark according to the strength of the mixture, all tones of colour obtained considerably deepen with subsequent exposure.

Terchloride of antimony one part to two of hydrochloric acid, the metals acid cleaned, immersed for 20 to 30 minutes, exceptionally well washed in many waters and then left for twenty-four hours in fresh water, dabbed and dried at a gentle heat, gives copper a film at first greenish grey and gunmetal a darker bluer green, both of which after a few days' exposure to the atmosphere tone to a permanent uniform dark blue green bronze.

Diluted hydrosulphate of ammonia gives emery cleaned copper the rich purple toned umber browns of Florentine bronze. Two or three minutes immersion in the cold fluid is employed for small objects and flooding and painting on for about the same time for larger, followed by draining off all accumulations of moisture and immediately subjecting the still moist work for a few minutes to a heat of from 180° to 200° Fahr. in a muffle or on a hot plate, and then brushing when cold to bring out a lustre. One part of the hydrosulphate to eight of water produces a rich lustrous dark purple brown, and twelve of water a similar but rather lighter tone. Sixteen, twenty-four and thirty-two parts of water yield progressively lighter shades. All these solutions are cumulative and very active, so much so, that a splash falling on the original cleaned surface of the metal instantly stains it brown, a mark which will sometimes remain visible as a darker spot in the colour arrived at at the termination of the process. With immersions, there-

fore, it is necessary to steadily and yet quickly plunge the object that it may be at once covered by the fluid without break of continuity; the difficulty is increased when the works are too large for this treatment, for these the solution is plentifully poured on from the top for it to run down and at once flood the whole work, and should it escape any spot, that has to be instantly wetted with a brush full of the solution kept ready for the purpose; after this, the liquid is uniformly painted on with the brush to keep the entire surface equally wet until the required depth of tone is obtained; the work should also be supported upon something smaller than its base to allow the superabundant fluid to drip from it, and also that all accumulations collecting at the base may be taken up with the brush and again spread over the work, otherwise the lower portions will be coloured more deeply than the remainder of the surface. Advantage is taken of this rapid accumulative action in toneing the Florentine bronzes in those in which some projecting portions are left of a lighter shade, effected whilst the work is drying but still just moist by continued painting upon the intended darker parts with a brush but moderately filled, so that its strokes may be thinned off at their edges to merge into and avoid those to be left lighter.

Hydrosulphate of ammonia mixed with from eight to sixteen parts of liquid ammonia, the process otherwise precisely the same as when diluted with water, gives equally good results to copper for the deep burnt sienna coloured Florentine bronze; and if the work be then subjected to the greater heat of 220° to 250° Fahr. it receives the third variety, the full coloured and nearly black bronze. It should also be said that with either the water or ammonia solutions, all accumulations to be removed should be taken up first with the brush and then with gentle touches with a clean soft cloth or blotting paper before the work is transferred to the heat, otherwise their more tardy evaporation is apt to cause stains; care in this respect is well repaid, notwithstanding that some portion of such stains will generally diminish when the cooled object is finally brushed or rubbed with a leather with or without a little powdered black lead.

Ammonia sensibly increases the activity of the solution which then requires somewhat more dexterity in application,

most preparations containing ammonia being very potent upon copper and gunmetal. In connection, it may be mentioned that these metals exposed for a few days in a closed vessel or under a glass shade to the vapour from a small saucer full of ammonia, become covered with its condensation in drops of blue green dew and this when washed off in water leaves them of a permanent verdigris green coloured granulation, precisely that of the corrosion upon long buried antiques.

Silver is readily oxidised and without any tendency to stains with the pure hydrosulphate of ammonia or with that diluted by one to eight times its bulk of water, used according to the depth of tone required ; the objects may be immersed in the cold fluid for about a minute or plentifully coated with the brush, drained and allowed to dry, or if they be dried off at 180° to 200° Fahr. the respective solutions give deeper shades. With all, the silver when first dry shows considerable green and purple iridescence which, however, entirely brushes off and leaves a uniform oxidation; a modified iridescence generally reappears a second or third time after a few days interval and when brushed off as before, the colour is permanent. A thick and dark slate coloured film of oxide, very difficult to remove, is obtained by a solution of half an ounce of sulphantimoniate of soda in six ounces of water, applied and dried off by heat, lighter tones by weaker mixtures, these show no iridescence and the colours remain as at first obtained.

The natural bronzing of copper, that is its tarnishing or oxidation from long exposure to the atmosphere, passes through a regular course; in its earlier stages of suboxide the film giving the colour is of a crimson to a brown red, with prolongation of time it passes to deeper browns and lastly to almost black, as the film formed on the surface contains larger proportions of oxygen; the brown oxide is noted by the chemist, Cu_2, O, that is as composed of two molecules of copper to one of oxygen, and the black as Cu_2, O_2, or two of each. One example of this natural oxidation could formerly be seen in the copper steam domes of locomotives, now mostly encased, which, from the heat within and the plentiful supply of oxygen without from constantly passing through moist air,

soon acquired a uniform and excellent brônze. The slow natural process may be both greatly accelerated and determined at any stage of its progress or colour, with the further valuable property that the film when thus artificially produced and arrested defends the metal to which it has attached from the otherwise cumulative action of the air, and remains itself permanently of the colour it has been permitted to attain.

Oxygen bronzing of small works in copper and gunmetal is very generally effected as follows. The work first chemically cleaned by immersion in a dilute acid bath, is washed and then coated with ordinary crocus powder mixed to a paste with water of about the consistence of thick cream, and immediately subjected for a few minutes to a regular heat of about 180° Fahr., held by tongs or placed in one of the wire loops, fig. 418, within a muffle, or, for other than commercial purposes and very conveniently, stood upon a piece of sheet iron over a spirit lamp. The heat is continued until all moisture is driven off and the coating caked hard, after which the crocus is removed by brushing in water and the work dabbed and dried. One such application gives copper a uniform film of red chestnut; a repetition a deeper and more Indian red colour, that usual upon presentation medals, and a third, a much browner tone of red which, however, is sometimes not quite so uniform. On gunmetal, one coat and heat produces a dusky gold coloured bronze, and a second and third the same in darker tones. In further experiments with other materials the author found that flour emery used in place of crocus applied once on copper gives a lighter redder chestnut, a repetition a fuller deeper red, and three times, a yet deeper and rather brown red. Oilstone powder, once, a uniform bright red of golden tinge, twice, a less golden red with some iridescence, and three times a deeper somewhat crimson red with purple reflections. With the paste made of powdered black-lead one application on copper gave a uniform rich brown of chocolate character, two, the same but darker; on gunmetal, once, an excellent yellow buff brown, and twice a browner buff colour.

The varieties of tones and colours obtained by the foregoing several powders, all used in precisely the same way, raised a question whether the powders themselves could possibly exert

any chemical action on the metals; but this was negatived when submitted to an expert and friend, Mr. Herbert Jackson, Chemical Demonstrator of King's College, London, who says, —"The colouring of the copper is due to oxidation of the heated metal by the oxygen of the air. If a piece of copper be heated alone in the air it bronzes and goes through various shades of colour to finally black. These colours are partly due to the film of oxide itself and partly to the action of light upon a thin film giving colours, as for instance in a soap bubble. When the copper is covered with a powder, such as crocus, the rapidity of oxidation will be much retarded and this will favour the formation of the lower oxide of copper or cuprous oxide (Cu_2, O) which is itself a red bronze colour. Probably the effects of different powders are to be explained mechanically. Some are finer than others, some mix better with water and again some when dried on the copper give an equal porous coating which is especially good for promoting slow and steady transference of the air to the heated surface of the metal. In connection with this question compare the protecting effect upon a piece of bright metal of even porous paper such as blotting paper. If a rod of bright copper be half covered with a single thickness of blotting paper, the part covered will remain bright or only slightly tarnished long after the uncovered portion has blackened. The paper appears to prevent the ready transference of fresh air to the copper, in fact it may be said to screen off the metal from currents of air which would be otherwise continually attacking the surface."

As evidence that the modification of colour is due solely to the degree of comminution of the powder, the author then experimented with oxide of copper itself, a far finer powder, and with white sand, a much coarser, than any previously used. The impalpable oxide of copper was difficult to mix coating the water into innumerable small globules which ran about like quicksilver, and when by long trituration this was reversed and each microscopic atom of the powder became moistened, the particles held so closely together as to form a semi-glutinous and almost impervious paste. When used this paste so obstructed the access of air as to produce only a very thin film of the earliest sub-oxide, a perfectly even, orange red

gold with uniform crimson iridescence and of great beauty, but so delicately thin as to be practically useless to withstand wear and tear. The sand produced the other extreme, a thick film of the darkest brown oxide, but irregular in colour, due to inequalities in the sand coating which at once shrank to unequal thicknesses from the rapid evaporation of its moisture.

Mr. Pinches, of London, who constantly employs this method for bronzing copper medals, frequently for hundreds at a time, uses crocus and prefers to limit the process to two applications, and he washes off the powder in a very dilute acid bath. In the rare case of failure in uniformity of colour the film is removed by re-immersion in the stronger acid cleaning bath, drying and gentle brushing with oilstone powder, after which the process is recommenced. The deep Indian coloured red bronze thus obtained is then usually enhanced in effect by finally striking every medal one light blow in the dies, which impart yet once more the high polish of their plain surfaces to the coloured ground of the medal, the relief upon which latter remains dull from its contact with the smooth but far less highly polished intaglio of the dies.

It occurred to the writer that analogous oxygen bronzing would result from the use of peroxide of hydrogen, a water-like fluid lately introduced for bleaching which contains from twelve to fifteen times its volume of oxygen, mentioned in the Catalogue, and his experiments have been successful. Copper immersed from fifteen minutes to one hour in peroxide of 12 vols strength, contained in an earthenware vessel and maintained throughout at a regular temperature of about 180° Fr., and when withdrawn stood to drain and dry without washing, is at first covered with a fine grey efflorescence, which, brushed off when dry, leaves the surface perfectly smooth with a uniform film of bronze varying in colour from red brown to deep brown oxide according to the time of immersion. After a few weeks exposure all these shades of colour become a little darker, the films are quite permanent and the liquid is particularly easy to use. The results are better when the ordinary acid bath cleansing is omitted and the metal cleaned with emery alone; on the other hand, if the copper be first immersed for about a quarter of an hour in a strong acid bath of one ounce each of nitric and sulphuric

acids to six of water and transferred wet to the hot peroxide of hydrogen, with similar times of immersion, it acquires equally uniform, permanent and serviceable films of rich greenish yellow brown buffs, that vary in depth of tone with the length of immersion. The defence afforded by all artificially produced oxide or other films against the otherwise progressive tarnishing or oxidation of metals from exposure to the atmosphere, already mentioned, is not only as marked with those produced by peroxide of hydrogen, but these films obstruct still further, inasmuch as, contrary to the action of most of the previously cited bronzing solutions, numerous trials show that although the depth of colour or thickness of the film to be obtained is progressive so long as the immersion in the peroxide is continued and uninterrupted, when that is terminated at any given point and the work has dried for a few days, the latter receives no increase of colour if the process be repeated upon it.

The process of browning gun barrels produces the colour and at the same time renders visible the figure or twist previously given to the metal, the effect of the ultimate result therefore mainly depends upon this preparation, a matter so interesting as to permit brief explanation. The filaments in fibrous iron somewhat vary in resistance to treatment by acids, so that if a smooth rod of this material be browned, in the manner to be presently explained, its individual fibres become more or less apparent on the surface as fairly parallel markings of deeper or lighter colours, a peculiarity ingeniously developed to produce the twist or figure in a gun barrel or the damascened markings on some sword blades. For fowling-piece barrels a number of thin pieces of fibrous iron of two or more qualities or sometimes both of iron and steel, about four inches wide by twenty long, are superposed alternately and the whole carefully welded into a bar of square section, which is then rolled down to a rod from five-sixteenths to half an inch square; the welds and innumerable fibres in which, therefore, all run in the one direction. Lengths of these rods are next heated and twisted until they assume the appearance of fine and regular quadruple threaded screws, after which either

three or four of these twisted rods are welded together all throughout their length, and this combined bar is then rolled down to the small square section; the operation being sometimes repeated with these second rods. Finally several of these more or less elaborated rods, their twists running in the same direction, or right and left, or in reverse ways from end to end, are combined by welding and are then rolled down to a section about three quarters of an inch wide by one quarter thick, and a piece of this last, about seven feet long, is coiled as a spiral and welded by its edges to form the barrel to be afterwards bored out true and shaped externally by grinding and filing. Exceptionally difficult and laborious, this twisting and marvellously perfect welding is carried out to absolute regularity, and, indeed, some highly skilled operatives can precisely copy the figure upon any given gun barrel, and the exact similarity in the figure, but twisting to right on the one and to left on the other, is a matter of common experience in double barrelled guns.

The browning mixture used at Birmingham for sportsmen's guns and rifles is composed of the following proportions and materials, viz., 4 ounces of black brimstone, 2 ounces of sulphate of copper, 4 drachms corrosive sublimate, 6 ounces tincture of steel, 1½ ounces nitric acid and 9 ounces of spirits of wine, and is applied as follows. The finished and proved barrels stopped at both ends by plugs of metal which also serve as handles, put in smeared with a little wax to prevent the liquids finding their way into the bores, are first placed for 10 or 12 hours in lime and water to remove all traces of grease; next they are well scrubbed with a wire scratch brush and washed in clean water, just prior to their subjection to the browning mixture. Some, as always done formerly, then boil the barrels in a bath of the clear portion of the above named solution diluted by its own bulk of water, in which, according to its strength or age, they are allowed to remain from a few minutes to about an hour. Withdrawn, so soon as the moisture has evaporated, they are well coated with lard oil, a variety mentioned in the Catalogue, and allowed to stand for some days; after this they are again lightly but well scrubbed with the wire scratch brush to remove all unattached colour, wiped clean and finished by repeated rubbing with the lard

oil, the smooth surface then showing the figure or grain of the metal in lighter and darker brown markings.

The process is by no means so simple as it would appear; a new bath colours but also rapidly corrodes the metal, which must be avoided, and when weakened by use it becomes somewhat irregular in its action, the time of immersion, therefore, has to be greatly varied, and beyond this, there are the necessary additions of the chemicals and of water to replace those lost by use and evaporation, hence invariable success with the bath requires aptitude and experience. A different procedure now more frequent avoids these difficulties; in this the scratched brushed barrels, washed clean of the lime, are boiled several together in pure water, withdrawn from which one at a time as wanted, they are held by one plug standing about upright on the other, the water almost instantly evaporates from the hot barrel which is then immediately coated from end to end with the undiluted clear portion of the browning mixture wiped on with a rag. Partially drying from the still remaining heat of the metal the colour is at first grey, and if from experience this be judged of insufficient depth of tone for its subsequent change, the browning liquid is applied a second or a third time; the colour becomes brown as the barrel thoroughly dries, aided by the before mentioned treatment with the oil and scratch brush.

The unfigured barrels of military rifles are coloured to a deep indigo brown by thus wiping on a mixture in the proportions of one ounce each of corrosive sublimate and sulphate of copper, in one ounce of nitric acid and two each of tincture of steel and spirits of wine, followed by the lard oil.

SECT. IV.—ORIENTAL LACQUERS.

In India, a thin liquid balsam, obtained by incision from the Dipterocarpus terminatus and one or two other trees, commonly known under the name wood-oil, is extensively employed as a varnish for general purposes, and also for the Burmese ware. For ordinary purposes the varnish is laid on with a brush, as usual; but for the Burmese ware the second and subsequent coats when laid are smoothed with the naked hand, in order to obtain a fine surface and to enable the work-

man to discover and reject any minute particles of dirt. When first applied the varnish has a light brown colour, but rubbing with the hand changes it to a fine black; after the works have been so treated they are carefully shut up in a box to exclude the dust, and then deposited in a deep cold vault for two or three days, treatment said to be essential to the proper hardening of the lacquer.

The Burmese cups of small size are made of thin strips of bamboo woven together like fine basket-work and these, as also larger specimens made in wood, are treated very much after the same manner as in the production of Japanese lacquer. After the first thick coat of varnish the interstices of the basket-work or joints in wood work, are filled up with a paste made of wood-oil mixed with different fine powders, such as calcined bones or very fine saw-dust from teak wood. After the paste has been smoothed with the hand, the work is again returned to the cold vault, and when it is sufficiently hardened, the surface is smoothed with pumice stone and water; the objects are afterwards varnished three or four times, and finally polished after the same general methods as are adopted in this country for varnished works.

Sometimes the cups are ornamented with raised figures which are made of the same paste that is used to fill up the interstices of the basket-work; the paste is pressed into tin moulds and afterwards transferred to the bowls, and when dry it becomes as hard as the solid wood. At others the cups are ornamented with engraved designs which are filled up with different coloured powders mixed with wood-oil, after which the surface is smoothed with wet bran held in the hollow of the hand; the operation is generally repeated to insure the complete filling up of all the lines, and the cups are then varnished and polished as usual.

A very good varnish is prepared by the Moochees with shell-lac and wood-oil, heated and mixed in small quantities. They also prepare a varnish for palanquins by melting sandarac and mixing it with boiled linseed oil rendered drying with litharge, but they do not usually add spirits of turpentine in the manner generally adopted in England for making oil varnishes. To give the appearance of gold to the silver leaf used for ornamenting the lacquers a little aloes is dissolved in

the varnish which is laid over it. Mr. J. Rhode, of Madras, says on this subject, "I know of no better or more durable polish, for teak or furniture woods than may be prepared by melting three or four pieces of sandarac of the size of a walnut or small egg, and pouring upon it a bottleful of linseed oil rendered drying by litharge or other drier, and after boiling them together for an hour, gradually adding while cooling a teaspoonful of Venice turpentine. It should be rubbed on the furniture, and after a little time, during which it may be exposed to the sun, rubbed off; the rubbing should be repeated daily and the polish should not be again applied for eight or ten days, after which it may be slightly applied every one or two months. Water does not injure this polish, and any stain or scratch may be rubbed over with it and obliterated, which cannot be done with French polish."

Japanese lacquer dates from remote antiquity, and records so early as 380 B.C. show that its manufacture was even at that time the subject of Imperial regulation. Kioto the ancient capital was the principal seat of the old industry, where decoration with gold, silver, mother of pearl, etc., was introduced; this city is still noted for superior ware, but the production of lacquer is now carried on throughout the Empire. All varieties of lacquers are made by the chemical or mechanical mixture of different materials with a natural varnish, the sap of the *Rus-vernicifera*, a tree native to Japan, the constituents and some peculiarities of which have been noticed in the Catalogue. Unadulterated if possible as collected from the trees, the sap is first strained through linen into shallow vessels, then placed in the sun for several days and stirred to evaporate its aqueous portion; when thus prepared it is mixed in small quantities, sufficient for the work in hand, with metallic salts, oil, finely ground earths, clays and stone, pigments and powdered metals to give it the required colours and body, and it is also used pure. Mr. Hikorokuro Yoshida, Chemist to the Imperial Government, mentions the following combinations as among those generally used.

Roiro or black lacquer, prepared by the addition of crude acetate of iron, usually *shaguro*, the native tooth dye; the mixture placed in the sun for two or three days is well stirred until, the iron combining with some of the urushic acid, it

acquires a jet black colour. Excess of iron is avoided, the least that suffices giving the better colour.

Shuiro or red lacquer; 20 to 30 per cent. of impalpably pounded cinnabar mixed with a little oil is thoroughly ground with the sap in a mortar, and the mixture strained. Smaller proportions of cinnabar give brown coloured lacquers.

Yellow and green lacquers are made in the same manner with realgar and orpiment, sulphides of arsenic found native in the volcanic districts, varying in depth of colour according to the quantities added. The mixtures in these cases are purely mechanical, the sulphides and cinnabar acting only as body pigments. Blue, purple or white lacquers are unattainable, as the sap, the base of the mixture, itself dries to a deep brown that destroys the effect sought.

Nuritate, the varnish used for the underlying coats, is compounded of the sap ground with oilstone powder, first moistened with water, to which a small quantity of powdered resin is then added. *Jōhana,* for the same purpose and made as above, has a little oil stirred in before use. *Nakanuri* or the varnish for the middle coating is the pure sap or ki-urushi from which all trace of water has been removed by long continued stirring in the open air; it is dark in colour and is used to give strength to the under priming coats. *Transparent* lacquer is made from pure sap of a quality that contains the least proportions of gum and nitrogenous matter, see Catalogue, diluted with about a fifth part of the oil of *Perilla ocimoides;* it is applied in the finishing coats and also in *Suruga* ware in which the grain of the wood-work remains visible through the lacquer.

Makiye the gold and silver lacquers, are made from pure ki-urushi very thoroughly mixed with from 30 to 50 per cent. of the metals, previously ground to the finest possible powders; they are applied generally in impasto or as tracery on previous coats of the plain lacquer, and the design in high or low relief, covered with a thin coat of transparent lacquer and polished, uniform in texture, has the colour and much of the lustre of the metals.

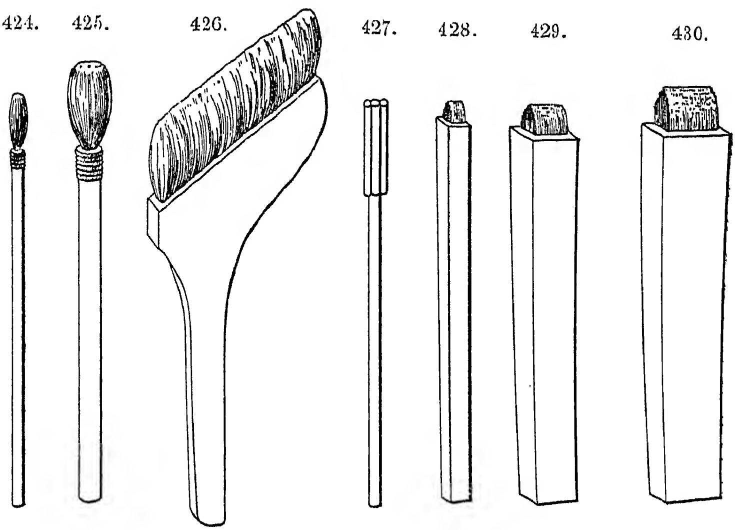
The perfect laying of the successive coats of the lacquer is effected with great dexterity with very primitive tools, and much time is required to allow each coat to dry hard before

applying the next. The method of producing the best Roiro or black lacquer is as follows: (1) The surfaces of the objects are scraped and polished perfectly smooth, after which every joint in those made of wood is neatly cut away into an angular groove throughout its entire length, which hollows are filled up with hemp fibre mixed with glue and rubbed down level, after which the whole work receives its first priming coat, a thin layer of the seshime-urushi. (2) A coat of the same mixed with its weight of wheat flour laid smooth to conceal all joints. (3) A thin coat of sabĭkô, a mixture of equal parts of the sap and jonōko, powdered burnt porcelain clay. (4) A coat of the seshime lacquer. (5) Another coat of sabĭkô. (6) Another of seshime. (7) A coat of kiriko, the jonōko diluted with seshime. (8) The surfaces thus far prepared, then have this body rubbed down perfectly smooth with a piece of native oilstone, similar in quality to water of ayr stone, and then blackened with japanese ink rubbed over them with cotton wool. (9) A coat of nakanuri or middle coating which, when hard, is rubbed smooth with charcoal made from the wood of the magnolia. (10) A uniform coat of the black Roiro lacquer, the preparation of which and of the previous lacquer has been already described, and this is rubbed smooth with a softer charcoal made from the wood of the Lagerstrœmia indica. (11) A second thinner coat of the Roiro lacquer rubbed on with the tip of the finger. (12) The surfaces are then carefully smoothed with powdered calcined stagshorn mixed with oilstone powder, which leaves them a perfectly smooth but dull black, a condition called *isuyakeshi* or rough surfaced. (13) Wiped clean from all dust of the last operation the work receives a final coat of seshime lacquer to render the black brilliant, and (14) this last coat is lightly polished, first, with a little of the stagshorn powder on soft cotton cloth and then with oil on the fingers, until it acquires its lustre.

From first to last, therefore, the work undergoes twenty-two distinct operations including eleven coats of differently prepared sap, required to produce the best quality of lacquer. Many of these successive coats are laid on with brushes of various sizes made of human, horse, hare, and cat's hair, figs. 424—430, of which some are peculiar in their short

spring like hair and rectangular stems. Others and all those for which the sap is mixed with the body pigments are laid flat and uniform with wood and other spatulas. Those used for large surfaces, fig. 419, are made from thin flat wood which the workman cuts out to their triangular shapes with the familiar short native sheath knife, and then, with the same tool, shaves away the surfaces until they taper regularly from the point to the wide straight base,

424. 425. 426. 427. 428. 429. 430.



the part used, leaving that as a thin feather edge; these implements vary from about 10 inches long by 6 or 7 inches in width at their thin edges for the largest, to quite small, some of which latter are variously curved at this portion, figs. 421—423, for laying the lacquer in mouldings, some of the smaller being made from slips of bamboo. The tool is held towards its thick pointed end between the thumb and fingers and is used both to mix the body lacquers and to lay them on the work.

For the former the operator places a small heap of the clay or other powder upon a smooth hardwood palette, arranges it in a hollow saucer-like form with an angle of fig. 419, then pours a sufficient quantity of the ki-urushi, seshime or oil in the center and thoroughly compounds the

two with the edge of the spatula, the process being a delicate miniature copy of our mode of mixing mortar, but it should be said that the author, in watching the process, has noted one result of long practice, viz., that the operator generally so closely estimates the quantities of the two materials that he very rarely has to add to either, and usually at once produces the desired consistency and also only just about the requisite quantity of the mixture for the particular surface to be covered. Immediately upon the mixing, the thick creamy result is lifted in moderate quantities by the spatula, held nearly horizontally, until the whole is transferred to the work, upon which it is then spread level and uniform in thickness over the surface by dextrous traverses in all directions of the edge of the spatula, then held nearly vertically, with a truth and rapidity equally remarkable. After a surface has been thus coated or when the lacquer has been laid on with a brush, the work is at once put aside until it has dried perfectly hard. For this the work is enclosed in an air-tight wooden box or cupboard, the rough unplaned inner surfaces of which are plentifully wetted with water to create a damp atmosphere which, contrary to the effect of moisture with our gum varnishes, greatly assists the natural drying properties of the sap; cold retards the drying, hence, in winter, the drying boxes are placed in a warmed room.

The coloured lacquers being thick from their body pigments, spread with more regularity and are more readily laid than the black Roiro and others which are chemically coloured and then strained, so that they do not differ in consistency from the pure sap. Precisely the same priming and body processes are followed up to the ninth, the application of nakanuri or middle lacquer and rubbing that smooth with magnolia charcoal, after which a coat of the red, brown, yellow or green lacquer is given, mixed and laid truly flat with the spatula as lately described, and, when dry, this is polished and the surfaces finished by rubbing with oil on cotton wool.

The foregoing refers only to the best lacquer; tough paper is used to strengthen the joints for lacquered wood ware of the second quality, which also receives fewer coats of the varnishes; the joints are left altogether unprotected in the low priced inferior wares, which latter first painted over with a strong

decoction of the fruit of the persimon tree, receive one coat of jonōko, ground smooth with charcoal, and then a final coat of the black or coloured lacquer.

Among the ornamental varieties that called *Hiramakiye* is decorated with lines and small patterns in gold, silver or tin level with the general surface. The work is prepared to its later stages and to the colour of the ground of the pattern, and the design drawn in a slow drying dextrine or glutinous material on thin transparent paper, is transferred to it by reversing the paper and gently rubbing the back of every line with a slip of whalebone, fig. 422, one pattern so drawn serving for many transfers. The design thus lightly marked on the work is first made plainly visible by a light dusting with white oilstone powder and then has every line traced with a fine pointed brush dipped in the ground work lacquer, and these portions immediately coated with the powdered gold, silver or tin picked up and lightly pressed upon them with cotton wool; after which every part that has been covered is gently stroked with a soft brush made of the coat hair of a horse, to smooth and consolidate the metallic particles and to remove all that are superfluous. When the ornament is hard the work receives a coat of transparent lacquer laid on with a soft brush, when dry a second coat, and this last is dried and rubbed level with charcoal and finally polished to a lustre with oil and a trifling quantity of the staghorn and oilstone powders rubbed on with the fingers.

Togidashi, a similar but bolder decoration, has the design brought out to stand just prominent by means of the polishing. The work prepared to the colour of the ground has the pattern painted upon it, or else transferred to it as lately described, in the same coloured lacker and coated with the powdered metal, and after it has received one or two coats of transparent lacquer, these are ground down with the slips of oilstone and charcoal but more between than upon the pattern itself, so that the design is left slightly above the general level of the surface; the last polishing is with oil and the powders on the fingers.

The impasto of *Takamakiye* or raised lacquer requires many further operations. The work prepared as for plain lacquer has the design painted upon it in the same colour and plenti-

fully dusted with powdered camellia wood charcoal, and when dry it is wiped and then washed with a brush fig. 426 and water to remove all unattached particles; a small quantity of pure ki-urushi is then rubbed over the surface with the fingers, followed by a coat of sabikō which, when dry, is smoothed first with the charcoal stick and then with powdered charcoal, and this stage is completed by a coat of transparent lacquer polished with the powders and oil. The pattern already slightly raised, is then built up by repeated paintings with the ground work lacquer until it acquires its desired height and forms, and is completed with some coloured lacquer in contrast to that of the ground or with the powdered gold or silver, after which the work receives a coat of transparent lacquer and is polished.

Keshiko, the most finely comminuted gold and silver used, is prepared from the beaten leaves of these metals, mixed with glue, the mass when dry ground to powder and agitated in water to separate the glue. *Uashijí* and *Hirame*, the coarser and more sparkling powders, are filings of the metals passed through fine sieves, the latter is the dust too coarse to be rubbed through; crocus, rottenstone, oilstone, burnt china clay and other powders are used, mostly as body or pigment colours.

Including those already mentioned there are altogether about twenty-five distinct varieties of Japanese lacquer, many of which are known by the names of the places where they are prepared, thus, *Tsugaru Nuri* ware is first prepared plain with a last coat of green colour, and whilst this is still wet, has yellow and brown lacquer worked in in irregular spots and masses. The Nuri ware made at Wakasa, similar as to its variegated ground, has the patches of added colour charged with thin morsels of gold or silver, placed either apparently at hazard, but really with consummate art, or else grouped in floral, figure and other designs. The pieces and lines of metal are pressed into the wet coat of ground work lacquer, when dry a second coat of the same lacquer follows and is ground away to the level of the metal inlay, after which the work receives a final coat of transparent lacquer and is polished. Mother of pearl, the same dyed, pieces of precious minerals, porcelain, ivory and other materials with and without gold and other metals are thus inlaid, always with beautiful effect,

often with surprising delicacy and minuteness; one example of old black Wakasa Nuri lacquer on copper in the author's possession, a surface measuring five by three inches, carries a brilliant and elaborate landscape, formed of upwards of 3,000 moderate sized pieces to minute specks of natural and variously stained mother of pearl, minerals, gold, etc., the copper and the lacquer together being but the one sixteenth of an inch in thickness.

END OF THE THIRD VOLUME.

INDEX.

C.

E.

F.

G.

H.

I.

J.

N.

O.

P.

T.

V.

W.

THE END

BRADBURY, AGNEW, & CO. LD., PRINTERS, WHITEFRIARS